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ИЗМЕРИТЕЛЬНАЯ
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CONTROL TRANSLATION SERIES

# Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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# Measurement Techniques

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MEASUREMENT TECHNIQUES

1959, Number 4 April

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# SOME PROBLEMS CONNECTED WITH THE APPLICATION OF RANDOM FUNCTIONS IN METROLOGICAL PRACTICE

G. S. Simkin

In estimating the accuracy of various means of measurement, one frequently uses the theory of random quantities or, what amounts to the same thing, the theory of random errors, whose characteristic property is the fact that they are independent of the parameters of the means of measurement. However, a closer study shows that such an approach is sometimes insufficient.

One often has to deal with random quantities or errors whose values depend on time or other parameters, for example, length, angle, temperature, pressure, etc.

Random quantities or errors which depend on one or a number of parameters are usually called random functions, in distinction to the usual random quantities, and the concept of a random function is more general than the concept of a random quantity.

In a number of cases the use of random functions in estimating the accuracy of means of measurement enables one to obtain a better estimate of their accuracy. Random functions may be used with great advantage to study the stability of the process of manufacture of measuring instruments.

By a random function one usually means a function which in each definite experiment may assume some special form, which, however, is not known in advance. The specific form assumed by a random function in a given experiment is called the realization of the random function. The development and application of the theory of random functions is mainly concerned with functions which have the time ($t$) as a parameter, and hence it is often called the theory of random processes, or the theory of stochastic processes [1, 2, 3].

However, the results obtained by the theory of stochastic processes can in many cases be successfully applied to random functions which have length, temperature, pressure, etc. as parameters.

Let us take an example from the field of linear measurement.

As a result of inaccurate manufacture of various parts and details of the mechanism of clock-type indicators, their readings suffer from errors and it is very improbable that these errors remain constant over the whole range of readings. It is more probable that these errors will change depending on the displacement of the movable rod. For different indicators this dependence will be different. One can therefore look upon the set of errors of a given indicator as one of the realizations of a random function whose parameter can be either the displacement of the movable rod or, what amounts to the same thing, the fraction of the rotation of the pointer. If one considers the set of errors of a large group of indicators, then it will represent a set of realizations of the random function.

Similarly to the theory of random quantities, which uses concepts such as the mathematical expectation, dispersion, and correlation (for two or more random quantities), the theory of random functions also uses such quantities, except that they are now functions of some parameter, i.e.,

$$m_x(P)=M[x(P)], \tag{1}$$

$$D_x(P)=D[x(P)], \tag{2}$$

$$\sigma_x(P) = \sqrt{D[x(P)]}\,, \tag{3}$$

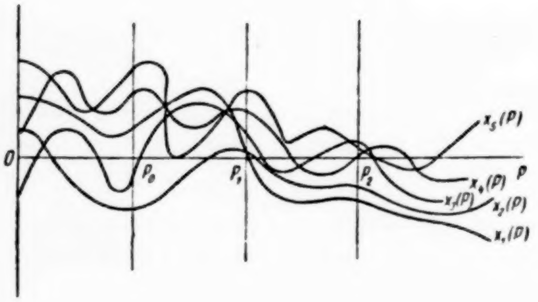
$$k_x(P, P') = M[x(P) - m_x(P)]\,[x(P') - m_x(P')]. \tag{4}$$

Here x(P) is a random function of the parameter (P), M[x(P)] is the mathematical expectation of the random function, D[x(P)] is the dispersion of the random function, and $k_x(P, P')$ is the correlation function which is sometimes also called the autocorrelation function.

In many cases it is more convenient to use normalized correlation functions which are defined by the relation

$$\rho_x(P, P') = \frac{k_x(P, P')}{\sigma_x(P)\,\sigma_x(P')}. \tag{5}$$

The quantities $m_x(P)$, $D_x(P)$ and $k_x(P, P')$, defined for a general set, are known functions. However, if they are determined from a limited number of experimental data then they must be looked upon as random functions whose accuracy must be estimated.




It must be noted that, in distinction to random quantities, in the case of random functions the most important quantities are the correlation functions $k_x(P, P')$.

Correlation functions contain more information than mathematical expectations of random functions and dispersion functions, since they enable one to judge the internal structure of the random functions, which cannot be done with the mathematical expectation nor the dispersion function.

Moreover, the dispersion function is a special case of the correlation function, i.e., $D_x(P) = k_x(P, P')$ when P = P'.

Let us briefly consider the methods of calculation of the characteristics of random functions.

Suppose that as a result of measurements or observations, one obtains a series of realizations of the random function shown in the figure.

Let us consider a value of the parameter P, say $P = P_0$. At this given value of P, all the realizations of random functions become the usual random quantities.

The relation $P = P_0$ is known as a section through the random function. On carrying out a number of sections through the realizations of random functions found from experiment, one obtains series of random quantities which may be used to determine the numerical values of the characteristics of the random functions.

TABLE 1

| 0 | 1 | 2 | 3 | $l$ | $n$ |
|---|---|---|---|---|---|
| $P$ / $x(P)$ | $P_1$ | $P_2$ | $P_3$ | $P_l$ | $P_n$ |
| $x_1(P)$ | $x_1(P_1)$ | $x_1(P_2)$ | $x_1(P_3)$ | $x_1(P_l)$ | $x_1(P_n)$ |
| $x_2(P)$ | $x_2(P_1)$ | $x_2(P_2)$ | $x_2(P_3)$ | $x_2(P_l)$ | $x_2(P_n)$ |
| $x_3(P)$ | $x_3(P_1)$ | $x_3(P_2)$ | $x_3(P_3)$ | $x_3(P_l)$ | $x_3(P_n)$ |
| $x_l(P)$ | $x_l(P_1)$ | $x_l(P_2)$ | $x_l(P_3)$ | $x_l(P_l)$ | $x_l(P_n)$ |
| $x_m(P)$ | $x_m(P_1)$ | $x_m(P_2)$ | $x_m(P_3)$ | $x_m(P_l)$ | $x_m(P_n)$ |

In the general form, the reduced sections through realizations of random functions may be arranged as shown in Table 1.

Column 0 of Table 1 gives the realizations of the random functions $x_1(P)$, $x_2(P)$ . . . $x_m(P)$ and columns 1, 2, 3, . . . $l$ . . . n give sections through these realizations for the parameters $P_1$, $P_2$, . . . $P_l$ . . . $P_n$.

Using the data given in Table 1, it is easy to determine the numerical values of the main characteristics for each section. Thus,

$$m_x(P_l) = \frac{\sum_{i=1}^{n} x_i(P_l)}{n}. \tag{6}$$

$$\sigma_x(P_l) = \sqrt{\frac{\sum_{i=1}^{n} [x_i(P_l) - m_x(P_l)]^2}{n-1}} \tag{7}$$

$$\rho_x(P_l, P_\kappa) = \frac{\sum_{i=1}^{n} [x_i(P_l) - m_x(P_l)]\,[x_i(P_\kappa) - m_x(P_\kappa)]}{\sigma_x(P_l)\sigma_x(P_\kappa)\,[n-1]} \tag{8}$$

Having determined from the data given in Table 1 the values of $m_x(P_1)$, $m_x(P_2)$ . . . $m_x(P_n)$; $\sigma_x(P_1)$, $\sigma_x(P_2)$ . . . $\sigma_x(P_n)$; $\rho_x(P_1P_2)$, $\rho_x(P_1P_3)$ . . . $\rho_x(P_1P_n)$ . . . $\rho_x(P_2P_3)$. . . $\rho_x(P_2P_n)$ . . . $\rho_x(P_kP_n)$, we obtain the discrete values of the functions $m_x(P)$, $\sigma_x(P)$, $\rho_x(P, P')$.

The problem then consists in the determination of the form of these functions.

For the general case, the determination of the form of the functions for a limited number of their values cannot be carried out, since a limited set of values can be described by an infinite number of curves.

However, the problem may be simplified if the form of the function is chosen arbitrarily subject only to the condition that it is the best approximation (in the sense that it has minimum deviations) to the set of experimental data.

The problem can then be solved with the aid of the method of least squares.

The form of the curve can be to some extent be "guessed" by drawing a graph through the experimental data.

Details of how such a curve can be chosen and of the method of calculation of its coefficients can be found in [4, 5, 6].

Below, we give the results of a determination of the characteristics of random functions for the errors of glass scales, the errors of indicators with smallest scale division of 0.01 mm and ranges of 0-10 mm and 0-5 mm, and also the errors of micrometers having a range of 0-25 mm.

Determination of the errors of glass scales. The errors of 20 hundred-millimeter scales taken from their test certificates were used.

To simplify calculations of the quantities $m_x(l)$, $\sigma_x(l)$ and $\rho_x(l, l')$, the errors of each ten intervals were averaged and ascribed to the mean interval.

The intervals were conventionally given the numbers 1, 2, 3, 4, etc.

Using equations (6), (7) and (8) we determined the numerical values of $m_x(l)$, $\sigma_x(l)$ and $\rho_x(l)$ which are given in Table 2.

A consideration of the numerical values of $m_x(l)$, $\sigma_x(l)$, and $\rho_x(l)$ shows that there is a definite dependence of these characteristics on the parameter $l$.

A graphical treatment of the numerical values of these characteristics, and the use of the method of least squares, led to the following relations for the above three characteristics:

$$\begin{aligned} m_x(l) = {} & [-1 + 6\sin(\varphi + 84°) + 3\sin(2\varphi + 84°) + \\ & + 1\sin(3\varphi + 170°) + 1.5\sin(4\varphi + 2°) + \\ & + 2\cos(5\varphi)] \cdot 10^{-2}\ \mu \end{aligned} \tag{9}$$

Here $\varphi = 360\, l \;\; 10$, where $l$ is conventionally taken to be 1, 2, 3, . . . 10 (i.e., the sequence of intervals into which the errors were divided),

$$\sigma_x(l) = (0.2 + 0.033l) \;\; \mu \tag{10}$$

$$\rho_x(l) = 1.18\; e^{-0.073l} \tag{11}$$

where $l$ = 1, 2, 3, . . . 10.

It must be noted that the observed periodicity of the function $m_x(l)$ is apparently due to the presence of a periodic error in the dividing mechanism which is used to inscribe these scales.

The above method of determination of the function $\sigma_x(l)$, which uses the theory of random functions, is much simpler than the method given in [4].

Determination of the errors of clock-type indicators. Here we used tests on 50 clock-type indicators with scale divisions of 0.01 mm and range 0-10 mm, and 50 indicators with range of 0-5 mm manufactured by the "Red Instrumentalist " works.

TABLE 2

| Scale interval | Interval No. | $m_x(l)$, $\mu \cdot 10^3$ | $\sigma_x(l)$, $\mu \;\; 10^3$ | $\rho_x(l)$ |
|---|---|---|---|---|
| 5 | 1 | + 3 | 20 | 1 |
| 15 | 2 | + 4 | 24 | 0.96 |
| 25 | 3 | 0 | 35 | 0.80 |
| 35 | 4 | − 6 | 34 | 0.84 |
| 45 | 5 | −10 | 36 | 0.70 |
| 55 | 6 | − 6 | 38 | 0.70 |
| 65 | 7 | − 4 | 42 | 0.68 |
| 75 | 8 | + 6 | 45 | 0.65 |
| 85 | 9 | + 1 | 48 | 0.55 |
| 95 | 10 | + 2 | 54 | 0.55 |

TABLE 3

| Revolutions | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | | | | | | | | | | |
| $m_x(l)$, $\mu$ | 2.2 | 1.8 | 2.3 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 | 2.0 | 1.6 |
| $\sigma_x(l)$, $\mu$ | 3.9 | 4.5 | 4.7 | 5.1 | 5.4 | 6.5 | 6.6 | 6.6 | 7.1 | 7.0 |
| $\rho_x(l)$ | 1 | 0.89 | 0.76 | 0.64 | 0.57 | 0.52 | 0.46 | 0.44 | 0.42 | 0.40 |

Table 3 gives the numerical values of $m_x(l)$, $\sigma_x(l)$ and $\rho_x(l)$ for the indicators having a range of 0-10 mm.

The data given in Table 3 show that $m_x(l)$ is not very dependent on the rotation of the pointer and hence one may assume that

$$m_x(l) = \text{const} = 1.9 \;\; \mu .$$

On the other hand, $\sigma_x(l)$ and $\rho_x(l)$ clearly do depend on the rotation of the pointer or the magnitude of the displacement of the movable rod.

The choice of the form $\sigma_x(l)$ and $\rho_x(l)$, and also the least squares calculation of the coefficients of these functions, gave

$$\sigma_x(l) = (3.7 + 0.37l) \;\; \mu \tag{12}$$

and

$$\rho_x(l) = 1.19\, e^{-0.13l} \;, \tag{13}$$

where $l$ = 1, 2, 3, . . . 10.

An analysis of the errors of 50 clock-type indicators with a range of 0-5 mm showed that

$$m_x(l) = \text{const} = 1.7 \;\; \mu \tag{14}$$

and

$$\sigma_x(l) = (3.8 + 0.40l) \;\; \mu \; . \tag{15}$$

Thus the quantities $m_x(l)$, $\sigma_x(l)$ may be considered as being the same for the two types of indicators.

This apparently shows that the technological process and the conditions of manufacture of such indicators is the same.

Determination of the errors of micrometers. We have also considered the errors of 100 micrometers having a range of 0-25 mm and manufactured by the "Kalibr" works, and 50 micrometers having the same range and

manufactured by the "Red Instrumentalist" works. Results obtained for $m_x(l)$, $\sigma_x(l)$ and $\rho_x(l)$ showed that they may be represented by

$$m_x(l)=(-1.2+0.08l)\ \mu \tag{16}$$

and

$$\sigma_x(l)=(1.8+0.05l)\ \mu \tag{17}$$

$$\rho_x(l)=1.5\ e^{-0.30l} \tag{18}$$

for the "Kalibr" micrometers, and

$$m_x(l)=(-0.05+0.08l)\ \mu \tag{19}$$

and

$$\sigma_x(l)=(2.3+0.025l)\ \mu \tag{20}$$

$$\rho_x(l)=1.6\ e^{-0.33l} \tag{21}$$

for the "Red Instrumentalist " micrometers.

Here $l$ is the displacement of the micrometers screw.

The present paper gives only results of an investigation of the accuracy of indicators and micrometers while in use, but the effect of this on their accuracy was not known.

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# ON SOME PROBLEMS ASSOCIATED WITH THE ORGANIZATION AND ACTIVITY OF FACTORY MEASURING LABORATORIES

K. N. Katsman

In the fulfilment of the resolutions of the Communist Party on the further growth of productivity in all branches of our industry, an important part should be played by the effective participation of factory laboratories in the development of new materials, technological processes, and manufactured articles. The activation of factory laboratories is being more and more frequently and widely discussed in the press. The discussion is mainly concerned with specific problems facing chemical, physical, and biological factory laboratories in the various branches of industry; and also the division of work between scientific research institutes and the laboratories which could increase the contribution of factory laboratories to the solution of various original problems. We thought it

might be useful to consider the activities of measuring laboratories from this point of view.

In many factories, measuring laboratories have not taken a leading part even in those activities in which, one might think, they would be particularly competent: namely, assimilation of the new methods of production particularly of new instruments, introduction of means of instrumental control (for example recording instruments) which would increase the output and improve the quality, and the reduction of costs of manufacture by the most rational choice of means of measurement and control.

Factory measuring laboratories were first organized in our country towards the end of the Twenties and the beginning of the Thirties. Further development of this system, particularly in the post-war period, took place under a strong influence of the Committee for measures and measuring instruments and its local agencies. This fact was conducive to the major growth of the network of factory measuring laboratories, but at the same time, has made its own specific imprint on the character of their activity having given it a somewhat onesided emphasis.

It is generally known that the main task of metrological agencies is to produce standards and to maintain the unity of measures by carrying out tests on instruments. The second part of this task was imposed on factory measuring laboratories by the local agencies of the Committee, and this aspect of their work became a dominating one. As a result, in spite of the terms of reference which imposed on the factory measuring laboratories a series of other functions, these laboratories have in many establishments become purely testing agencies. It is no accident that the heads of measuring laboratories in various establishments are often referred to as "responsible for the unity of measures."

Of course, by far not all laboratories have limited themselves to purely testing work. A considerable number of laboratories contribute new ideas to the technology of industrial measurements and are engaged in systematic work in this field. However, there is undoubtedly an even greater number of laboratories which are entirely organized within the narrow "checking" framework. In particular, VNIIM has often been approached by heads of various measuring laboratories with requests to protect them from attempts by factory administration to "burden" them with various accurate measurements required by the industry. Such requests were treated by them as improper, since they considered that the task of these laboratories is exclusively limited to the testing of instruments.

There is no doubt that checks of means of measurement and the maintenance of the unity of measures are extremely important functions of factory measuring laboratories, but at the same time, however well this is done by these laboratories, they can at best merely maintain the level of technical measurements which has so far been reached. In order to make the next step something new is required, namely, originality in one form or another.

The main task of factory measuring laboratories is not the maintenance of the unity of measures, or even the supervision of measuring apparatus, but generally, to ensure the correctness of results of technical measurements and methods for the quantitative estimate of physical quantities in industry, both by studying them on the spot and by the use at all stages of the manufacturing process sufficiently accurate, reliable, cheap, and productive means and methods of measurement. Such a purpose is in our opinion more peculiar to factory laboratories. Testing activities are very important but are only a part of this more general task.

In a review of the methods of estimating physical quantities which are employed in industry, we have the right to expect a considerable amount of original work. First of all, we shall undoubtedly discover a large number of "black spots" by which we understand such industrial operations and processes where so far instrumental control is entirely absent, and physical quantities are estimated by eye, on the basis of training and experience of workers and technicians. At the present time, the staffs of the majority of the measuring laboratories simply bypass such facts, or more frequently, simply don't know about them. This is explained by the fact that at the present time, the laboratories are responsible only for the state of the instruments, and since there are no instruments there is nothing to look after. Moreover, such processes are frequently sources of waste and other losses.

Frequently, instrumental control is not used because it involves a large personnel, or takes a considerable amount of time. These difficulties may be overcome with the aid of automatic sorting devices and other automatic measuring instruments.

There is scope for original work in those industrial processes where instrumental control exists but is carried out only periodically. Any chemical, textile or food industry can supply many examples of this, since in such cases a large number of quantities is determined not through continuous control at the place of manufacture, but by taking samples and then examining them in the factory or departmental laboratories. Particular attention should

be paid by the staff of the laboratories to those sections of industry where in order to carry out the measurements, the manufacturing process must be interrupted. In these cases losses are very large and the introduction of methods of measurement which are free from this disadvantage promises considerable benefits for the particular undertaking. Tests which involve the destruction of manufactured or semimanufactured goods are in an analogous position.

The use of highly specialized instruments, especially produced for the control of a given specific detail of a process, can often considerably increase the accuracy of measurement, ensure an economy in time, and give a cheaper instrument compared with a universal one.

In other words, the scope for original work in the improvement of the technology of industrial and other measurements is unlimited.

In order to improve the methods of industrial measurement, it will be necessary to produce a large number of new measures and instruments. It is clear that the full development of a large part of new means of measurement is beyond the powers of factory laboratories, although one could give many examples where small factory laboratory staffs have successfully carried out serious development work. In any case, factory measuring laboratories, simply because of their position, should be well aware, and apparently are aware, what kind of new means of measurement a given undertaking requires. We consider that factory measuring laboratories should at least be able to put forward requests for the design of new instruments necessary to the given undertaking, and try to ensure the realization of such requests through the appropriate organizations. There are quite a few laboratories which could already do this work. But what is the true state of affairs?

During the past year we took part in the work of a National Economy Council which was concerned with the planning of the manufacture of instruments at a number of undertakings in the Leningrad economical district. An integralpart of this plan is, as is well known, the development of new, and the modernization of the existing, instruments. One would expect that the most important source for such plans would be requests from the large number of factory measuring laboratories sent through the appropriate National Economy Councils, KB,* instrument manufacturing works, or other organizations. However, there were almost no such sources. Moreover, the plans of the KB and of the instrument manufacturing works included rather far-fetched suggestions, given either in an obscure form without indicating the output specifications, or topics borrowed from foreign sources and being entirely irrelevant under our conditions, etc. In the face of specific problems developed by factory laboratories and scientific research laboratories, there would simply be no room for such suggestions.

If the laboratories are to work successfully in the improvement of industrial measurements, there must be a plan from which it would be clear in which sections of the industry, and at what time, a study and an analysis will be made of the existing method for estimating physical quantities and the accuracy and reliability of the results of such estimates; where, on which operations, sections, and when, a new technique of measurement will be introduced, and what exactly it consists of; what would be the technological and economical effects on the undertaking of the completion of this work. This must be brought to the attention of both the laboratories themselves and of the controlling organizations, in particular, the regional state control laboratories for measuring techniques.

An extension of the range of work of the measuring laboratories is prevented by the existing form of their organization. In the majority of undertakings there is a single factory measuring laboratory, and in addition, there are disconnected sections in the form of electrical measurements laboratory, laboratory for linear and angular measurements, thermotechnical laboratory, and others, which are a part of the various departments. Such sections are usually not well staffed, and being a part of the department, not very imposing. From the technological point of view, the isolation of such sections is harmful, since modern means of measurement tend to unify elements which have previously existed in isolation. Even in such classical branches of optical and mechanical measurement as, for example, more accurate measurements on end standards, measurements of stress, mass, etc., one now has to use electronics, quite apart from other fields in which electronics has long been used and will continue to be used. Moreover, in many branches of electrical measurement, one must have a knowledge of optics. It is thus more correct to unify these laboratories into a central factory measuring laboratory, to be responsible to the chief engineer. The least understandable is the tendency to subordinate these organizations to the technical control section, regardless of the decisive role which is now played by measuring devices in technological (particularly automatic) lines.

*Design office.

In conclusion, a few words on the relationship between state control laboratories for measuring techniques and factory laboratories. As before, the main method of work of the state control laboratories is through a large number of inspections carried out under the guise of so-called important revisions, or in the form of short visits which more frequently than not show show very little profit. The most common state of affairs consists in a search for various small shortcomings.

It would be desirable to cut down on the number of all the possible inspections and to replace them by systematic work with factory laboratories, and in particular, a joint study of the possible ways of improving industrial measuring techniques at separate undertakings, taken as typical representatives of various relatively specialized branches with similar technology, in order to use the results for all the related objects. The cooperation of the corresponding institutes in setting up program, and in the discussion of the results of such work, would increase its value and make it more realistic. The generalization and active transmission of on-the-spot experience of factory laboratories, well organized technical information on national and foreign achievements in measuring techniques, the correction of plans of factory laboratories, the division of labor between laboratories of various undertakings, and the supervision and assistance in the fulfillment of plans, all these would be of much greater benefit than episodic inspections.

## INTERNATIONAL SYMPOSIUM ON INTERFEROMETRY

The international symposium on interferometry took place at Teddington (Middlesex) between June 9th and June 11th, 1959. About 20 major papers were read at the symposium. An exhibition was held during the synposium and the symposium proceedings will be published.

# LINEAR MEASUREMENTS

## INCREASED ACCURACY OF MEASUREMENT BY MEANS OF TAPE MEASURES

B. E. Kostich

In heavy engineering, especially in the production of overhead crane spans (GOST 7131-54) in transport engineering, etc., details with a tolerance of ±3-5 mm in a length of 20 to 45 m are common. The accuracy of assembly stands is of the order of ±1 mm in 20 m. In checking lengths under shop conditions, however, sagging of tape measures is compensated by increased tensioning which produces error of the order of 10-15 mm [1].

In order to determine how to decrease the total error let us find what produces the component errors: $\Delta_1$ the error of scale calibration, $\Delta_2$ the error of reading, $\Delta_3$ the temperature error, $\Delta_4$ the error due to the lack of parallelism between the tape-measure scale and the axis of the detail, $\Delta_5$ the error due to the extension of the tape measure under strain, and $\Delta_6$ the error due to sagging.

Actual dimensions of tape-measure scales up to 10 m are known with an accuracy of ±0.5 mm, and of tape measures of 20 m and over with an accuracy of ±1 mm [2], such corrections, however, are not used, as a rule, in shop measurements. The reason for neglecting these correction is due both to the predominance of errors $\Delta_5$ and $\Delta_6$ and to the difficulty of using the normal calibration chargs.

However, specifying deviations at each meter interval in terms of 0.5 mm according to GOST 7502-55, should simplify the calibration chart by including in it only the aggregate deviations of the meter devisions along the whole length of the tape measure, i.e., from zero to each meter division. Then the error of the tape-measure scale from zero to any division will equal the difference between the absolute value of the error for the entire length and the local deviation of the meter interval, and it will not exceed 0.5 mm, i.e., it will be within the specification limits.

Such a simplified correction chart can be affixed toeach tape-measure case.

Thus,error $\Delta_1$ in our case will consist of the deviation at meter intervals $\Delta_d = \pm 0.5$ mm and the specified over-all error of the tape measure for 10 or 40 m, $\Delta_s = \pm 0.5$ and ±1 mm, i.e., $\Delta_1 = \sqrt{\Delta_d^2 + \Delta_s^2} = 0.7$ and 1.1 mm which is considerably smaller than the permissible aggregate errors of scale calibration.

Let us assume the error of reading $\Delta_2$ in shop measurements to be 0.5 mm. The reading error due to two measurements of a detail will be $\Delta_2 = 0.5 \cdot \sqrt{2} = 0.7$ mm.

The temperature error is found from the known formula:

$$\Delta_3 = l\left[\alpha_1(20^\circ - t_1) - \alpha_2(20^\circ - t_2)\right].$$

Assuming the difference of the shop ambient temperature and the normal temperature to be 8°C, the difference of temperature between the detail $t_1$ and the tape measure $t_2$ to be 0.5°C, and the difference between the linear temperature coefficients of the detail and the tape measure to be $\alpha_1 - \alpha_2 = 4 \cdot 10^{-6}$ mm/m·degree, we obtain $\Delta_3 \approx 35 \cdot 10^{-6} l$ mm, where $l$ is the length of the detail in mm.

Thus,under the imperfect condition of shop inspection of detail lengths of 20 to 50 m,the temperature error of measurement is not the decisive factor for improving accuracy.

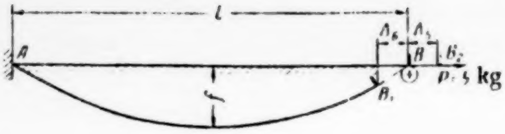


Fig. 1.

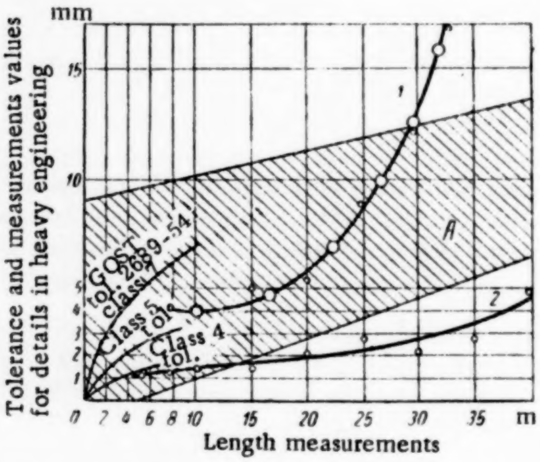


Fig. 3. A is the region of distributed tolerance values for details in heavy engineering.

TABLE 1

| Length measurements, m \ $\Delta P$ in kg | 1 | 2.5 | 4 | 5 |
|---|---|---|---|---|
| 10 | 0.25 | 0.62 | 1.0 | 1.25 |
| 20 | 0.5 | 1.25 | 2.0 | 2.5 |
| 40 | 1.0 | 2.5 | 4.0 | 5.0 |

TABLE 2

| Length measurements, m \ $P$ in kg | 5 | 7.5 | 9 | 10 |
|---|---|---|---|---|
| 10 | 0.34 | 0.18 | 0.12 | 0.1 |
| 20 | 3.2 | 1.5 | 0.9 | 0.8 |
| 40 | 25.6 | 11.5 | 8.0 | 6.5 |

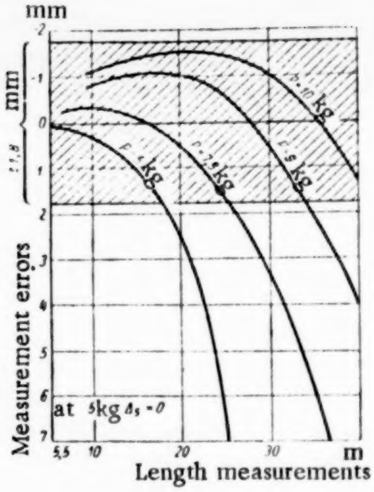


Fig. 2.

Assuming the maximum deviation from parallelism between the axes of the tape measure and the detail to be 60 mm in 10 m (~ angle 0° 21'), we obtain the value of $\Delta_4$ = 1/50,000 as the difference between the tape measure and its projection (cos 0°20'40" = 0.9999818).

The largest errors $\Delta_5$ and $\Delta_6$ are due to the elastic strains of flexible linear measures. In [2] the length of a tape measure is taken as the distance between its graduations when the tape is placed on a horizontal plane and subjected to a tensile force of 5 kg.

A freely suspended tape measure occupies a position represented by a catenary (Fig. 1). Let us assume that with a tensile force of P = 5 kg the tape measure occupies during testing a position shown by line AB. When measuring with the same but sagging tape measure, let it occupy position $AB_1$ under the effect of its own weight and the tensile force of 5 kg. The measurement of the length of a chord by means of a sagging tape measure always involves a reading greater than the actual length by $\Delta_6$.

A tape measure with tension increased above 5 kg and placed on a plane will read less than the actual value by $\Delta_5$.

The value of $\Delta_5$ due to tensioning greater than the specified amount of 5 kg can be found from the formula:

$$\Delta_5 = \Delta l = \frac{l \Delta P}{EF},$$

where $\Delta P$ is the increased tension in kg, $l$ is the

length in cm, E and F are the modulus of elasticity and the tape cross section (0.02 $cm^2$) respectively.

The value of $\Delta_6$ can be determined from formula

$$\Delta_6 = L - l$$

where $l$ is the length of the chord AB, L is the length of the catenary curve,

$$L \simeq l\left(1 + \frac{8}{3} \cdot \frac{f^2}{l^2}\right)$$

where $f$ is the sag in the tape ($f = gl^2/8P$, here $g$ is the weight of the tape in kg per 1 cm length, P is the stress at the lowest point, and $l$ is the length of the chord).

The values at several lengths of $\Delta_5$ for various $\Delta P$, and of $\Delta_6$ for various P are given in Tables 1 and 2 respectively.

The total error of ($-\Delta_5$) and ($+\Delta_6$) is shown in Fig. 2. It will be seen from Fig. 2 that for each length there is an optimum tension of the freely suspended tape measure at which the systematic errors ($-\Delta_5$) and ($+\Delta_6$) cancel each other to a great extent, i.e., ($-\Delta_5$) and ($+\Delta_6$) tend to a minimum.

For a practical application of this proposition, it is possible to restrict $\Sigma\Delta_{5:6} = f(l, P)$, to $\Sigma\Delta_{5:6} = \pm 1.8$ m, which holds in the majority of cases.

The limiting error $\Delta \lim_{\Sigma p}$ of measurement by means of sagging tape measures can be found from the formula given below, provided that the aggregate errors of the scale are corrected, and that "the most appropriate tape tension is employed, where $\Delta_5 + \Delta_6 < 1.8$ mm, and the variations in tensioning do not exceed $\pm 0.1$ kg.

The above expressions were derived with the assumption that the transverse natural frequency $\omega_{0\,trs}$ of the converter was not lower than its longitudinal natural frequency $\omega_0$.

$$\Delta \lim_{\Sigma p} = -\Delta_5 + \Delta_6 + \sqrt{\Delta_1^2 + \Sigma\left(\Delta_{5;[\Delta P = 0.1\,kg]} + \Delta_{6;[\Delta P = 0.1\,kg]}\right)^2 + \Delta_2^2 + \Delta_3^2 + \Delta_4^2}.$$

Taking above values of $\Delta_{1-4}$ assuming they have a normal distribution, neglecting values $\Delta_{5;[\Delta P = 0.1\,kg]}$ and $\Delta_{6;[\Delta P = 0.1\,kg]}$ caused by the tensile force instability of 0.1 kg [3], we obtain the value of $\Delta \lim_{\Sigma p}$ represented by curve 2 in Fig. 3; curve 1 was obtained with a tensile force variation of $\pm 2$ kg.

Thus, in using the most appropriate tension and a simplified calibration chart of errors for meter divisions only it is possible to measure lengths up to 40 m with a total limiting error reduced to 1/10,000 of the measured length.

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[2] Instruction 89-55 on checking metal tape measures, Committee of Standards, Measures and Measuring Instruments, [in Russian] (Moscow, 1958).

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# MEASUREMENT OF DEFORMATION BY MEANS OF PORTABLE INDICATORS

A. A. Kravtsov and A. F. Shchurov

It is not always convenient or possible to use stationary instruments for measuring deformations of structures and their members. If the tests are prolonged and the number of positions large, a considerable number of instruments is needed which, in unfavorable conditions (excessive humidity, adverse environment, etc.) often fail, and make the tests difficult. In these conditions it is advantageous to use portable instruments with which it is possible to measure deformations at several points. In addition, portable instruments enable measurements to be made with greater gage lengths; for tension tests these devices can be used by "reversing" them, thus obtaining maximum deformations at the rupture.

The Gorkii Civil Engineering Institute employs portable devices for measuring deformations of fabricated beams under prolonged loading, for determining the physicomechanical properties of timber and in the study of the deformation properties of concrete; these devices were developed by the authors.

The portable device (Fig. 1) consists of a dial gage, and a device consisting of the sleeve 2, spring 3, screw 5, and the locknut 4, attached to the gage.

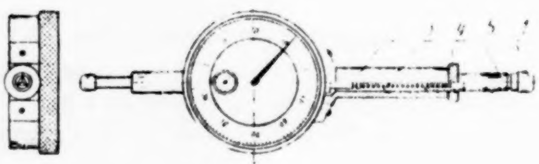


Fig. 1.

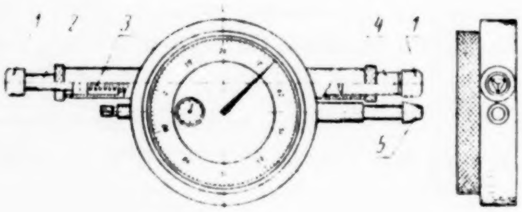


Fig. 2.

The plunger of the dial gage and the screw 5 have heads 1 at their ends, with pyramidal holes in their end faces; these holes take the spherical points of pins.

The gage length is set by means of the screw 5 and the locknut 4. The device can be set for "forward" or "reverse" operation.

In determining the deformation by measuring the mutual displacement of two points, a portable device (Fig. 2) is used.

The sleeve in the left-hand part of the device, which is screwed to the dial gage, carries a freely moving rod 2 with the spring 3 and the head 1, while the sleeve in the right-hand part of the device carries the screw 4 with a locknut.

The spherical contact piece on the plunger of the dial gage is replaced by the head 5 with a flat polished flat face.

For measuring deformations of fabricated beams by determining the mutual displacements of its components parts, pins are fixed to the beam at the points of displacement on two beam components: thereupon the heads 1 and 5 of the right-hand part of the device are brought in contact with these pins.

The head 1 of the movable rod 2 is brought in contact with the third pin (which is secured to the beam) thus fixing the device securely in position for the duration of the test.

Two types of fixing pins are used. One type consists of the steel pin with a pointed lower end which has a hole drilled in its side, with another pin to which a 3-4 mm diameter ball is soldered, which is inserted into the hole in the first pin.

The fixing pin of the second type consists of a strip cut from steel sheet to which a ball is soldered and a wooden pad to which the strip is bonded.

The pins of the first type are intended for testing concrete and the second type is used for testing timber.

The points of the pins of the first type are inserted into holes previously prepared in the material, and bonded to it by means of a gypsum solution or an adhesive, while the pins of the second type are simply bonded to the material.

The accuracy of the portable devices is determined by the accuracy of the dial gage which is used with them. The accuracy of readings is affected by the temperature of the surrounding air since,at the time when the readings are taken,the temperature of the instrument rises and its length increases. In order to avoid temperature errors,the readings should be taken in a strictly maintained order, and measures should be taken to prevent the warming of the device by the hand of the investigator.

The devices described can also be used as stationary instruments for measuring deformations caused by short load applications; in this case the greater range of movement represents their main advantage over ordinary lever-type strain gages.

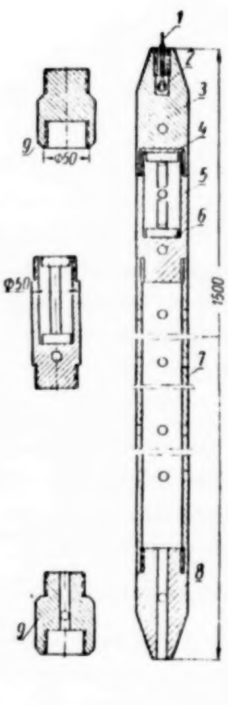
## DEVICE FOR MEASURING THE CURVATURE OF BOREHOLES

M. P. Panov

Various methods are used for determining the deviation from its vertical position of a borehole during the boring of oil or gas wells; as a rule,hydrofluoric acid is used for etching glass plates, in order to record the curvature of the bore. This acid is dangerous in transportation and must be stored in special vessels.

In order to overcome these disadvantages and to reduce the costs of measurements without affecting their quality, the author developed – in cooperation with I. M. Chirko – a new method of measuring the curvature: in this method the etching of glass is replaced by the bleaching of photographic paper blackened by complete development with a mixture of hyposulfite and potassium ferricyanide.

The design of the device based on this principle is shown in the figure.




The measuring unit 5, which is sealed by means of the rubber gasket 4, is mounted inside the cylindrical body 7 with the upper (3) and the lower (8) tapered guide members. The upper guide member 3 is screwed to the body and had a roller 2 for fixing the wire rope. 1. The lower guide member 8 is also threaded, which makes it possible to fix an additional weight when the device has to be made heavier in order to increase the speed of its descent through a heavy solution. By fixing a wooden block, the buoyancy of the device can be increased, thus slowing its downward speed. The lower guide member 8 and the tube 7 have a number of holes which reduce the speed of the device when it is thrown into the borehole. The measuring unit of the device consists of the body 5 and the paper holder 6. The photographic paper which records the measurements is tightly pressed against the inner wall of the body 5, by means of the paper holder 6. The body is about half filled with the solutions of hyposulfite and ferricyanide. Assembled in this manner the device is used for measuring the curvature of 4-in boring pipes.

If the same device is used with boring pipes of other diameters, additional rings 9 of a diameter corresponding to that of the pipe are screwed between the upper tapered guide member and the measuring unit. Similar rings are screwed at the connection between the tube 7 and the guide member 8.

The device operates as follows. When lowered into a curved borehole,it assumes an inclined position and the axis of the measuring unit forms an angle with the vertical. The solution, whose level remains horizontal, bleaches the photographic paper, reproducing a clear image of the boundary of the solution-air interface; the top portion of the paper remains black while the lower part becomes white. The angle formed by this dividing line and the bottom edge of the photographic paper is equal to the angle of curvature of the borehole. Its size is measured by means of the angle gage developed by the author.

The angle gage consists of a metal plate which forms the base of the device. The 90 × 120 mm hole in its center takes the photographic paper. Two slides, upper and lower, can be moved along the base. The top slide is graduated in degrees and carries a movable pointer-arrow. The axis of the pointer is located between the slides, while the other end moves on the scale.

For measuring the angle, the photographic paper is inserted in the hole of the base plate of the angle gage and covered with a glass plate. If the bottom slide is placed against the minimum level of the curved line which divides the black and white portions of the paper, and the upper slide is placed against the crest of the curve, a gap remained between the slides. The size of this gap can be read in degrees and minutes on the scale.

The bleaching liquid which is filled into the measuring unit is of the following composition: 1% solution of hyposulfite and 3-8% solution of potassium ferricyanide. For preparing the working liquid both these solutions must be mixed in the following proportion. For boreholes with a temperature up to 70°C: 10 parts of hyposulfite solution and 1 part of potassium ferricyanide; for boreholes with a temperature exceeding 70°C: 20 parts of hyposulfite and 1 part of potassium ferricyanide.

The solution becomes active 8-10 minutes after mixing and becomes inactive after 18-20 minutes.

The intensity of the process reaches its maximum 12 to 18 minutes after mixing.

The duration of the process and its speed depend on the concentration and the proportion in which both solutions are mixed, and can be varied within a wide range: beginning at 1 to 17 minutes and extending to 12 to 34 minutes.

Solution already mixed cannot be used repeatedly.

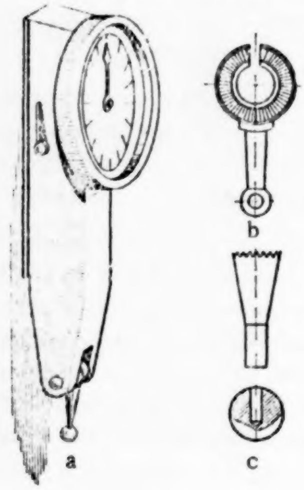
Stoppages during the lifting or lowering of the device do not affect the results of measurement, since after 30 minutes the solution is no longer active and cannot produce a second reading.

The advantages of this method include the absence of a meniscus, since the thin top layer of the liquid is unable to whiten the photographic paper and so introduce an error. The dividing line is extremely clear and sharp, thus enabling the readings to be taken with an adequate accuracy.

## REPAIR OF LEVER INDICATOR NIPPLES

S. V. Aronova

When the spherical measuring nipple of a lever indicator is worn (see Fig. a) it is usually necessary to make a new nipple (Fig. b). This is a very labor-consuming operation since it is necessary to cut teeth on the ratchet. For this reason the Moscow Light Automobile plant has adopted the following more efficient method of repairing nipples of lever indicators.




The worn sphere is filed down to a cylinder 1.5-1.6 mm in diameter (Fig. c). Next a required size ball is selected and a hole to the depth of 1/2 its diameter drilled in it. The size of the hole is chosen to produce a tight fit. The ball is then pressed on to the cylinder and soldered with a low temperature solder. Finally it is polished with a fine-grained paste.

This method is justified although the repair takes a considerable time.

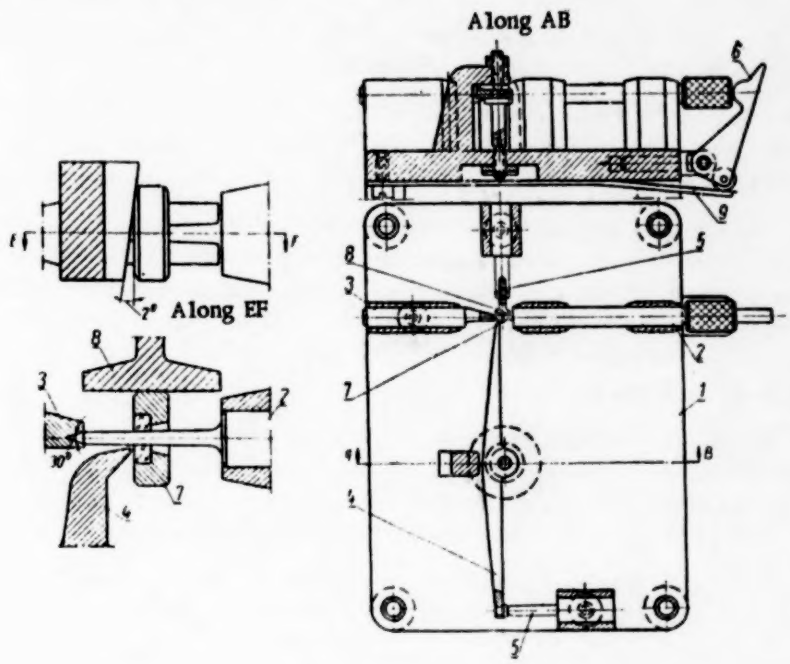
It is possible to press-fit by this method in addition to ball nipples, tips of any other shape.

## A DEVICE FOR CHECKING WOBBLE IN SMALL BEARINGS

I. M. Efuné

In instrument-making, it is normal to use bronze bearings and holders with agate or corundum bearings in order to decrease friction in gear and spindle journals.

In order to ensure accurate distances between gear centers, the wobble in these bearings and bearing holders must not exceed permissible limits. It is difficult to check wobble in these details owing to their small diameters, down to 0.4 mm, and a comparatively large tolerance specified for them.




An indicating device developed by the author for this purpose is shown by the attached figure. Supports for an interchangeable mandrel 2, a centering bearing 3, lever 4 and two indicators 5 are mounted on base 1. For placing the detail to be tested in position sprung lever 6 is tilted, releasing mandrel 2, on whose tapered end shaft the tested detail 7 is firmly fixed, measuring feeler 8 of the radial wobble indicator is withdrawn, mandrel 2 pivot engaged in centering bearing 3 and held in position by means of lever 6 which is operated by spring 9. In the operating position the feeler of lever 4 rides on the end surface and indicator feeler 8 on the external diameter of the detail under test. By rotating the mandrel with the attached detail through 1 or 1.5 turns the end and radial wobble is measured on the indicators. The mandrel end shaft has a taper of 1 : 100. Mandrels 2 are made with assorted end shaft sizes for every diameter of the tested bearings.

The testing lasts 5 sec.

# STANDARDIZATION OF MEASURING EQUIPMENT FOR CHECKING LINEAR AND ANGULAR DIMENSIONS

N. I. Zimin and D. D. Malyi

According to the recommendations of the State Planning Commission of the USSR and the State Scientific and Technical Committee of the USSR Council of Ministers the compiling of a plan for progressive standardization of measuring equipment for checking linear and angular dimensions was entrusted to the Interchangeability Bureau (BV) with respect to the production of instrument-making plants of the former Ministry of Machine-Tool Industry of the USSR, to the Central Scientific Research Institute of Heavy Engineering (TsNIITMASh) in the sphere of checking large dimensions and to the State Optical Institute (GOI) with respect to optical and opticomechanical instruments for checking linear and angular dimensions in engineering.

By the middle of 1958 the Interchangeability Bureau compiled and submitted for discussion to wide technical circles a plan for standardizing measuring equipment for checking linear and angular dimensions, approved by a Commission of the State Scientific and Technical Committee of the USSR (Standartgiz, 1958).

Comments and proposals regarding the standardization plan were received from more than 350 engineering plants, technical administrations, and engineering agencies, Councils of National Economy of the main economic regions, Institutes, Design Offices, and State Inspection Laboratories. The plan was discussed at special seminars of Technical Inspection Department workers in Moscow and Leningrad. It should be noted that such a wide participation of technicians in discussing standardization is unprecedented, and the liveliness of discussions indicated the topical nature of the proposals.

Over 100 plants and organizations are in complete agreement with the standardization plan. Comments and proposals of the remaining plants in all the spheres of standardizations without a single exception deserve careful consideration with the object of improving the accuracy of the original plan by joint work of the authors of the plan (BV) and metrologists and technicians in the engineering industry.

In this article it is impossible to examine in detail all the suggestions and comments (about 3,000) and we will therefore restrict ourselves to the examination of addenda to the plan.

Gages. The plug-gage sizes of 0.05-0.3 (in steps of 2.5 $\mu$) and 0.3-15 (in steps of 10 $\mu$) suggested by the 3rd Watch-Making plant (Moscow) are special size gages whose requirement is limited and whose mass production would not be justified.

We accept the 6th State Bearing plant's suggestion to standardize cones with a 1:12 taper supplied on order. The suggestion of one of the plants to standardize plug gages for checking internal threads should be re-examined after the forthcoming revision of the thread-cutting GOST (State All-Union Standard).

We agree with the standardization of thread gages 5 M (proposed by the Automobile Repair Plant of the Moscow City Council) according to GOST 8724-58. Standardization of adjustable rings 4-100 and their k-calibers U-PR and U-NE (proposed by the "Dormash" plant in Orel, the electromechanical plant in Khar'kov and the "Kraskyi Ekskavator" plant in Kiev) is not advisable. It is generally known that these rings are not widely used in industry owing to the difficulty of their repairs which require special equipment; for the same reason these expensive adjustable rings are used, as a rule, at fixed dimensions.

We agree with the proposals of the 3rd Watch-Making, the "Krasnyi Gidropress", and other plants for extending standardization to: a) thickness gages 0.015-0.020 (on order), b) gages for checking spline joints (on order). The suggestion of the "Avtotraktorodvigatel' " plant (Tambov) for standardizing feeler gages for checking piston-ring grooves cannot be accepted owing to the special nature of the gages and their limited requirement.

Block gages. It is advisable to extend standardization to sets of micron block gages. It does not appear to be at present advisable to standardize quartz block gages (proposed by the experimental plants in Moscow and Malakhovka, and the Perm State Control Laboratory). End gages 0.10-1.0 in steps of 2 $\mu$ (proposed by the OMV plant, Revda) are not specified by a GOST and therefore there is no point in standardizing them.

Slide Gages. A number of factories recommend the extension of standardization to specialized slide gages. We cannot agree with this suggestion. Slide gages recommended by the Odessa (GKL) State Inspection Laboratory for checking parallelism of dovetail slides and those recommended by the Odessa Automobile Assembly Plant for checking diameters of narrow hollow chamfers of holes, etc., cannot be adopted by instrument-making plants since they are not universal and their use is limited. The suggestion of the Odessa GKL and the Odessa Automobile Assembly Plant to produce slide gages with an indicating device is also impracticable, since such a device would greatly complicate production and raise costs and would not be justified by only a moderate increase in the facility of its use.

The suggestion of the "Dal'sel'mash" plant of producing slide gages for marking out small diameters deserves consideration.

The suggestions made by several plants to produce 0.05 slide gages with a tempered bar and versions of 0.02 mm slide gages and height gages are also impracticable. In the first instance, their durability will not be improved since slide gages fail mainly due to the corrosion of the bar and wear of the measuring surfaces and in the second, slide gages with a vernier scale division of 0.02 mm cannot be recommended owing to their poor metrological properties.

Nor it it possible to include in the standardization list of mass-produced articles height gages with a rack-guided movement of a 300-500 mm frame (as suggested by the Minsk Spare-Parts plant) and height gages with a moving scale of 100-500 mm and 100-750 mm type VEB owing to the limited use of such gages.

Micrometer gages. Production of light micrometers is suggested by the "KIM" (Kuntsevo) and other plants. This is a reasonable suggestion, so are the suggestions of the Yaroslavl' Cable plant, the Kiev "Ukrkabel" plant, the OTsM factory (Revda) and the Kar'kov "Yuzhkabel' " for including in the standardization micrometers with a restricted range. Specialized factories should produce these micrometers in order.

The suggestion of the Poltava PRZ and other plants to produce micrometer gages for internal measurements is impracticable since specialized plants already produce indicating inside calipers.

Universal Measuring Instruments. The suggestion of extending the standardized range of internal calipers for measuring holes smaller than 3 mm in diameter is supported by several plants and research organizations, including the Assembly plant (Vinnitsa), the Ural Wagon-Building plant (Nizhnii Tagil) and others.

A group of plants considers it necessary to produce measures and measuring machines.

Other plants insist on the production of indicators of the dial type with a measuring range of 0-25-30 mm.

Several large and small engineering plants consider it necessary to produce instruments for checking centers 1,000-1,500 mm apart at a height of 200-300 mm.

Several plants (the Turbo-Mechanical plant in Poltava, the "Krasnoe Sormovo" plant in Gor'kii, and others) recommend to include in the standardization plan equipment for checking sheet metal thickness and walls of details in places removed from the ends of the products.

In addition to similar proposals, which add to the standardization list, many proposals originated from consumer plants and were of a specialized nature.

Keeping in mind the requirements of the engineering industry and the advisability of putting articles into mass production, the standardization list of universal measuring instruments should be extended by the inclusion of: instruments with an extended scale on the basis of optical measuring machines (proposed by the Leningrad Instrument plant); conical hole gages for holes smaller than 3 mm in diameter; optical measuring machines with scale divisions of 0.1 $\mu$ and a range of $\pm$0.012 mm; optical spring measuring heads with scale divisions of 2-5 $\mu$ and a range of $\pm$30 divisions; a geared lever measuring head with scale divisions of 5 $\mu$ and a range of 0-2 mm; 0-30 mm dial indicators with scale divisions of 0.01 mm; instruments for checking centers separated by 1,000-1,500 mm; sheet and wall-measuring gages for measuring in places removed from the ends of the articles.

The limited use of certain special measuring instruments makes it inadvisable to include them in the standardization list, such instruments include indicators of the pendulum type for measuring radii Combine plant, Krasnoyarsk); instruments for measuring internal cylindrical grooves, instruments for measuring tapered holes 6-20 mm in diameter to a depth of 150 mm and other instruments.

It is impossible to agree with the proposals of the TĚMZ (Tomsk), MZMA and other plants for including in the standardization list of instruments of the measurer and measuring-machine types, indicators type "Federal" with scale divisions of 2 and 1 $\mu$ and other foreign made instruments, when there exist Soviet instruments of the same type which are not inferior to the former in their metrological properties.

Equipment for Measuring Angles, Planes and Parallelism. It is impossible to agree with the proposals to include instruments which are not widely used (such as 0-360° goniometers with a scale division of 5' and an extended bar suggested by the Lepitsk Tractor plant; spherometers proposed by MZMA, instrument for measuring radii of circles inscribed or circumscribed to an angle of 90° suggested by "Dal'sel'mash" and others). The proposal of the Moscow Machine Tool plant to include on the list hydrostatic levels (made by the ĚNIMS) and suggestions by some other plants (the Kherson Shipbuilding Yard, Stalingrad Medical Equipment plant and others) to extend the list by including cylindrical squares (on order) should be accepted.

Sixteen plants, including the Kirov plant (Leningrad) the 1st GPZ, ZIL, and the Minsk Tractor plant suggest inclusion in the list instruments for checking smoothness and linearity.

The greater part of the suggestions are well founded but belong to the type of instruments which should be, as already stated, dealt with by GOI.

Some of the received suggestions should be considered in connection with the standardization entrusted to BV (Interchangeability Bureau). The standardization should be, for instance, extended to french curve rules over 300 mm (on order) as suggested by some plants. The suggestion of ZIL (Lenin plant) for including in the standardization list notched gage blocks (made on order) should be accepted.

Thread Measuring Equipment. Several factories insist on including in the standardization list instruments for measuring internal threads. Plug gages are a reliable means of checking small and medium diameter threads; for checking large diameter threads instruments designed by the BV should be used, these instruments have shown their worth in checking internal and external threads in the oil industry. The suggestion to include in the standardization wires of diameters greater than 4 mm and devices for checking buttress threads S = 2-12 mm should be accepted. The mistake made in the standardization list should be corrected and the production measuring equipment (supplied on order) as well as roller and collar snap gages included in the section dealing with checking threads, (suggested by the Kirov plant in Leningrad). Plants which produce wires for checking threads should also make anvils for micrometers which should be standardized. The suggestion of the Machine-Tool Instruments Institute for including equipment for checking guide screws on the standardization list should be accepted.

Special types of instruments should not be included in the list in this section of instruments any more than they were in other sections. Well founded proposals of several plants to include on the list blades for checking threads should be referred to the GOI when it considers the optical instruments for checking linear and angle measurements.

Equipment for Checking Roughness of Surfaces. The majority of the contributors request to include in the standardization list, equipment for checking the roughness of internal surfaces. These requests should be considered and the list amended. Several plants propose supplementing the standardization by samples of clean surfaces for nonferrous metals. These suggestions will be considered in connection with the new standards for clean surfaces now being developed.

Some factories propose to include in the standardization list equipment for checking surface roughness the type of profilographs made by foreign firms. It would appear that the contributors who made this proposal were not acquainted with the Soviet made profilograph of the "Kalibr" plant type VĚI whose high metrological and operational qualities are known and have been commented upon, particularly at the Brussels exhibition.

Equipment for Checking Gear and Worm-Gear Drives. The Kirov plant (Leningrad) proposes to include in the list instruments for checking standard gear wheels and dividing discs and superposed pitch gages of the type made by the firm Maag for basic and circular pitches M12-10 with a scale division of 1 $\mu$. Universal instruments with an angle-measuring dial, which are standardized, provide efficient checking of standard gears and precision discs and the forthcoming modernization of instruments for checking circular and basic pitches, provided for in the present standardization, will meet the requirements of the Kirov and other plants.

One of the Leningrad plants recommended to include in the list Filatenko's instrument for complex two-profile checking of gears with a low module. This proposal is worth noting; a decision will be made after the technical and economic efficiency of this proposal has been considered.

We cannot accept the proposal of certain plants (including that of the Parkhomenko plant in Lugansk) for the inclusion of evolventometers made by the firm Maag for gear wheels 1,000 mm in diameter, since the standardization includes already a Soviet made evolventometer for wheel 800 mm in diameter, which should meet the requirement. Neither can we accept the proposal to include a tooth gage bench for checking low module gear wheels M0.15 and of higher values, since it has no advantage as compared with the instrument for checking low module gears already included in the standardization list.

We consider it necessary to accept the proposal coming from a group of plants to include standard gear wheels M0.3-1 (having provided a specification for these gear wheels) and to extend the range of universal module measuring instruments down to 0.3.

The instrument proposed by the Kryukov Wagon-Building plant for checking the accumulated error of circular pitches of the Zeiss type is inferior in its metrological properties to the universal instrument with an angle calibrated dial included in the standardization list.

The proposal of several plants to include instruments for checking gear wheels with a module less than 1 mm should be accepted. The VB has developed a modernized stage for a measuring microscope, which provides checking of gear wheels with a module down to 0.5 mm. This design should be included in the list.

The Ural Car Building plant proposed to include in the standardization list a set disc evolventometer of 150-180 mm in diameter. The standardization however, already provides for a universal instrument serving the same purpose. On the other hand we agree with the plant's proposal to include in the list, standard gages for internal gearing M2-10.

The Khar'kov State Institute of Measures and Measuring Instruments (KhGIMIP) and the Moscow Machine-Tool plant (MSZ) recommended to include in the list a superimposing evolventometer for checking gear wheels of a large diameter. This suggestion should be accepted and Klingel'nberg's design adopted.

The inclusion in the list of universal instruments for checking kinematic accuracy of internal gear wheels (proposed by MSZ) is impracticable since the differences between instruments of this type will consist only in varying devices for securing the gear wheels which can be carried out in each case according to the customer's orders.

We accept the MSZ proposal to include in the standardization list instruments for checking the kinematic accuracy of large-size gear wheels without taking them off the machine. In this connection, the plant's proposal for including in the list stationary instruments for checking large gear wheels does not appear to be necessary.

The standardization provides a stand for checking large gear wheels. This should meet the proposal of the Odessa "January Rising" plant for checking radial wobble in large gear wheels.

It is necessary, according to the suggestion of one of the factories, to provide a more accurate specification for the wave meter indicating its limits of measurement starting with M 1.5.

The proposal of one of the Khar'kov plants to include in the standardization list an instrument for checking lateral clearance between the teeth of engine distributing gears is of a narrow specialized nature.

The desire of the Saratov Gear-Shaper Manufacturing plant that semi-automatic and automatic checking equipment for tapered gear wheels be included in the standardization list should be met and the equipment supplied on order.

The universal instrument which is provided in the standardization and has a dial for measuring angles can also be used for checking tapered gear wheels; thus the request of the Kiev Tramcar Building plant for a special instrument for checking tapered gears becomes irrelevant.

It is necessary to include in the list, equipment for checking Novikov's gearing (proposed by the KhGIMIP).

Equipment for Measuring Cutting Tools. Contributors suggest extending standardization to new highly specialized equipment to be produced in instrument-making plants. It is, as in similar previous cases, inadvisable to accept such proposals.

However, in response to suggestions made by several plants, it is advisable to exclude from standardization universal instruments for checking gear cutters M 0.5-2.5, and replace them with universal instruments for checking gear cutters with continuous checking over several revolutions. In this instance, cutters M 0.3-2.5 and M 2-16 should be provided with checking means. It should be noted that an instrument for checking low modules has already been developed by the VB and another one for medium modules can be developed on the same principle.

The Kirov plant (Leningrad) proposed to include in standardization, Druzhinin's instrument for checking all the elements of high-precision gear cutters. The Moscow Instrument plant, however, is using a standardized instrument which provides the same checking facilities as those provided by the Druzhinin instrument.

Equipment for Automation and Mechanization of Inspection. Certain specifications proposed by the consumers reflect the variety of possible orders for devices of operative and reception inspection.

Special Means of Measurement. The inspection equipment listed in the standardization specifications does not cover all the devices used in various branches of industry and would not cover them even if it were extended still further. It seems to us that the equipment produced on order will have to be specified by direct negotiations between the customers and producers.

The main defect of the proposed standardization is the lack of specifications for devices to check the testing equipment. Proposals made by 130 plants to include such equipment on the standardization list confirms the necessity of this measure. It is necessary to include in the list equipment for checking micrometers, end gages, slide gages, goniometers, squares, indicator gages, plug gages, surface plates, rules, etc., especially so, since the design of several such instruments has been developed by the VB on the basis of the experience gained by various institutes (KhGIMIP, VNIIK), State Inspection Laboratories, and plants. The designs have been submitted to various plants ("Kalibr" and others) for mass production on order.

The proposed standardization plan does not include, as we have already pointed out, large-size checking equipment which is dealt with by the TsNIITMASh. The necessity for this development is confirmed by the persistent requests from some of the largest engineering plants.

Some 250 plants sent in about 600 proposals to cover measuring instruments with hard alloys. These suggestions will be taken into consideration when the final standardization plan is worked out; it is most likely that specialized plants will be recommended to cover, with hard-alloy layers measuring surfaces of 50-60% of their universal measuring instruments.

The consuming plants as a rule demand a speeding up in the time allowed for mastering new production (300 proposals). The manufacturing plants on the contrary demand an increase in the time allowed (20 proposals).

Probably, in the final version of the standardization plan after a detailed discussion of this question with the manufacturing plants and the appropriate Councils of National Economy, these time limits will be fixed keeping in mind the requirements of the engineering industry.

## PRODUCTION OF SPARE PARTS FOR MEASURING INSTRUMENTS AND GAGES

V. N. Shchukin

Not all the establishments are able to repair measuring instruments by making worn and broken components themselves. The manufacturing plants often do not make spare parts. In slide gages with a scale division of 0.05 and 0.1 mm, for instance, the vernier scale wears out before the remaining parts, yet there are no spare vernier scales.

The 0-125 mm slide gage has a constructional defect consisting in its vernier scale being engraved on the main frame of the instrument. It is not long before the vernier scale begins to exceed the zero mark of the slide. The "Kalibr" plant should make slide gages with a detachable vernier scale. In dial indicators of the "Krasnyi Instrumental'shchik" plant the pinions and geared racks usually wear out first. Spare pinions should be supplied with the indicators. The gearing should be cut on both sides or all around the measuring rod in the same way as it is done in Czechoslovak instruments.

The lack of spare catches in indicating 6-10 mm inside micrometers puts them out of action if a catch is broken. Some establishments unable to make the spare part have to scrap valuable instruments.

The manufacturing plants must organize the production of spare parts. This will prolong the life of measuring instruments and gages.

# MECHANICAL MEASUREMENTS

## APPARATUS FOR MEASURING CUTTING FORCES IN TURNING

A. A. Voronin

The set of equipment to be described was developed at NIAT for recording the three components of the cutting force involved in turning; it consists of standard components,and instruments used in conjunction with special devices made up from NIAT drawings. It includes a TDV-2 fast three-component lathe dynamometer, a three- or four-channel amplifier for wire strain gages (with rectifier, stabilizer, and set of microammeters [1]), an MPO-2 loop oscillograph, a calibrator PTV-2 (with a set of calibration plates), and certain other accessories.

Figure 1 shows the TDV-2. The body 1 has ways for setting the dynamometer on the top slide of the lathe. The main part (the shaped cone 2) is made from 65G spring steel. The rear end of 2 is made as an elastic hinge and membrane with a thickened rim, which is held tightly in the body 1 by screws. The front end is made as a standard cutting tool held mechanically, in which the cutting instrument 3 is held by a bar and screw. In this way the clamping force and heat produced by cutting are prevented from affecting the readings.

The front end is held by four hollow rods 4, which are adjusted by the cap screws 5. A similar fifth rod is fitted axially at the rear end.

Figure 2 shows the elastic system schematically. The components $P_z$, $P_y$ and $P_x$ act on rods I-V, which deform elastically.

These rods carry wire strain gages R and K, which serve to measure to the deformations.

One component $P_y$ compresses rod V; rods I-IV and the membrane bend. The bending stresses in rods I-IV are not recorded, because the strain gages are so placed and wired that these stresses are without net effect. Therefore the instrument records only the stresses causing extension or compression.

Further, in each pair I-II and III-IV,one rod is in tension when the other is in compression. Therefore the gages on a pair of rods are connected in adjacent arms of the bridge. This increases the sensitivity and effects temperature compensation.

Temperature compensation is ensured for measurements of $P_y$ by fixing two compensating gages on top of the recording ones, but with the axes crossed, as shown in Fig. 3.

The gages are connected via leads and terminals to the three-channel amplifier.

The TDV-2 is calibrated after it has been set up on the lathe, for which purpose a special device is used. This device (Fig. 4) subjects the dynamometer to a steady force equivalent to the resultant of all the forces acting in cutting. Therefore,the calibration and use conditions are almost identical. The sole difference is that in the first case the forces are static. This, however, is quite permissible with a fast dynamometer.

The device is set up between centers, or in the chuck with support from the back center. The calibration plate 1 is set up at the cutting point; it has inclinations $\alpha_1$ and $\alpha_2$ in the YOZ and XOZ planes respectively.

The rim and body are turned to bring the axis of the stem 2 into a position normal to the plane of the calibration plate.

The screw 3 drives the stem 2, which acts via a ball on the spring dynamometer 4, and hence P, the force acting at a known point on the calibration plate, is measured. Then $P_z$, $P_y$ and $P_x$ are given by

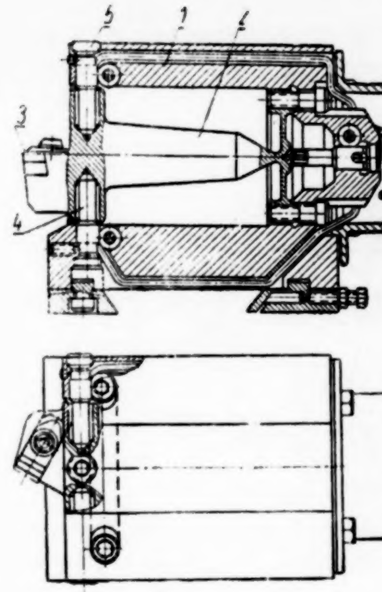



Fig. 1.

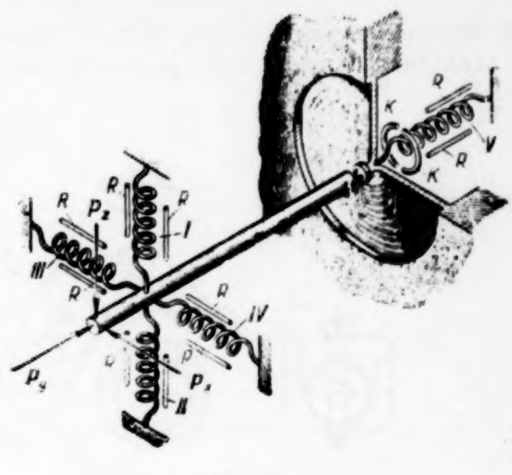



Fig. 2.

$$P_z = \frac{P}{\sqrt{1+\mathrm{tg}^2\alpha_1+\mathrm{tg}^2\alpha_2}}$$

$$P_y = \frac{P\,\mathrm{tg}\,\alpha_1}{\sqrt{1+\mathrm{tg}^2\alpha_1+\mathrm{tg}^2\alpha_2}},$$

$$P_x = \frac{P\,\mathrm{tg}\,\alpha_2}{\sqrt{1+\mathrm{tg}^2\alpha_1+\mathrm{tg}^2\alpha_2}}.$$

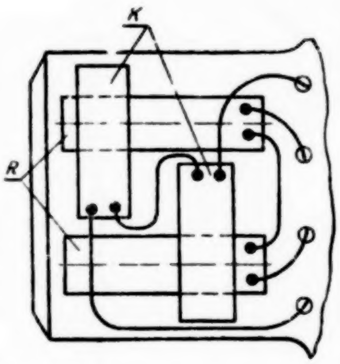



Fig. 3. R working gages, K compensating gages.

where P is the force normal to the inclined calibration plate, $\alpha_2$ is the inclination of that plate in the YOZ plane, and $\alpha_2$ is the inclination in the XOZ plane.

Dynamometer 4 is used to adjust the load in steps of 50 or 100 kg over the working range. The three meters are read appropriately. The results are used to draw up graphs such as those of Fig. 5, which are used to work up the oscillograph records or meter readings. The stability of the apparatus may be checked by inserting a standard resistance in one arm of a bridge, which throws the bridge out of balance by a known amount. This amount is equivalent to a certain load, in kg.

In this way it is possible to test dynamometers thoroughly, and to determine their more important characteristics.

The main errors in fast dynamometers are [2] caused by defects in the design of the elastic system and in the manufacture of the strain gages. The elastic system of fast dynamometers is such that they are subject to unmeasured displacements that deform them as well as to the measured displacements. The gages record these unwanted displacements to extents dependent on their type, design, and site in the device.

The absolute and relative values of these unwanted displacements depend on the loading conditions and on the detailed design of the device. Therefore, in any particular case, it is important to establish the absolute values of the errors for those particular conditions.

In a lathe dynamometer, the load conditions change in the following main ways: the relations between the components change, because the cutting force itself changes in magnitude and direction; the point of application of the resultant force varies somewhat; the temperatures and thermal deformations of the parts vary; and the clamping force on the tool varies.

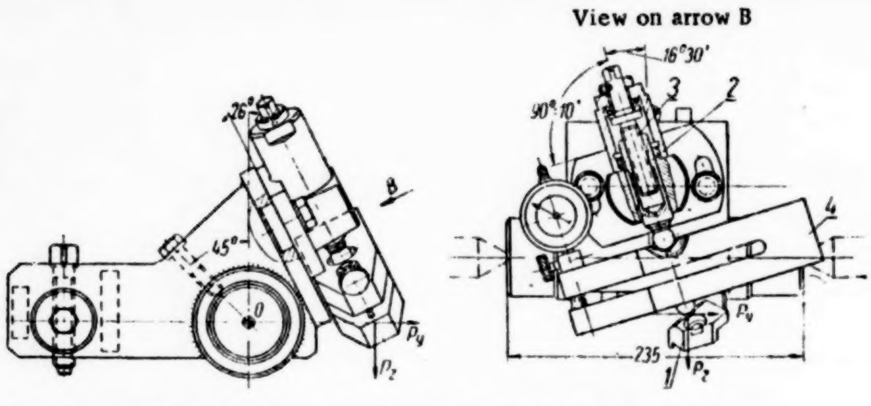



Fig. 4. The PTV-2 device for calibrating lathe dynamometers.

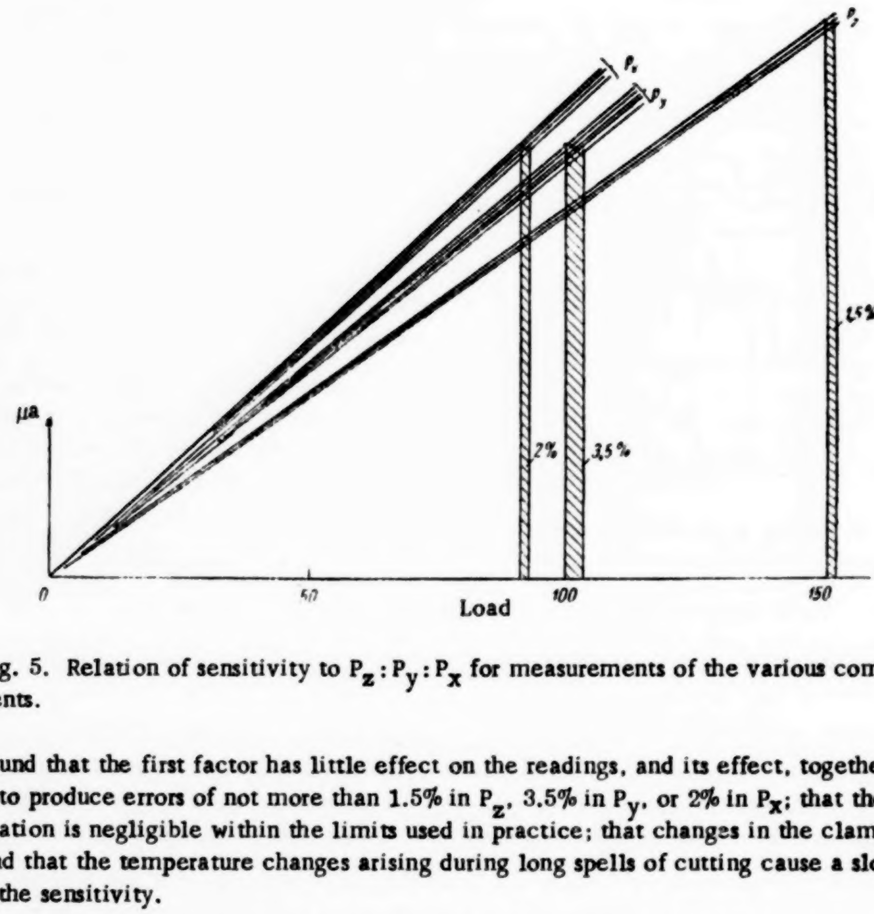



Fig. 5. Relation of sensitivity to $P_z : P_y : P_x$ for measurements of the various components.

We have found that the first factor has little effect on the readings, and its effect, together with certain random errors, is to produce errors of not more than 1.5% in $P_z$, 3.5% in $P_y$, or 2% in $P_x$; that the effect of change of point of application is negligible within the limits used in practice; that changes in the clamping force are without effect; and that the temperature changes arising during long spells of cutting cause a slow drift in the zero, but do not affect the sensitivity.

Many tests and prolonged practical use have shown that the apparatus is suitable for recording slow and fast changes in cutting force within the range 20 to 600 kg at any cutting speed used in practice.

The instrument is insensitive to vibration, is very rigid, and has a natural frequency not less than 2300 cps.

The three components are recorded either from the meters or from the film of the MPO-2 oscillograph (type IV coil).

The total error of measurement of $P_z$ is about ±4%.

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[1] M. B. Geogievskii, S. V. Cheredov and M. D. Medvinskii, "A multi-channel measuring instrument (PÉT-3V) for use with wire strain gages," in Experimental Methods of Studying Machines [in Russian] (Akad. Nauk SSSR, 1954).

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# AN INSTRUMENT FOR CHECKING THE FORCE OF A THERMOSTAT BELLOWS


Yu. M. Gonikberg


The bellows (Fig. 1) is the main sensing element in the thermostat of a domestic refrigerator; it has a tube soldered to one end. The gas (Freon 12) is sealed in. The test conditions require that the bellows should exert forces within the limits 1.3 to 4.2 kg for two given values of A (distance from flange to end) when the tube is inserted in succession in baths at temperatures of − 9 and − 18° C, respectively.

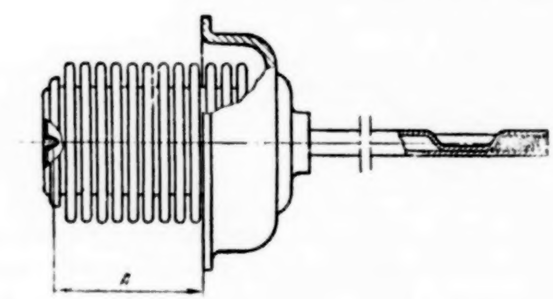

Fig. 1

We have made a special instrument at the Likhachev Motor Works (Moscow) in order to measure these forces (Fig. 2). The bellows 1 is held by its flange in the body 2; the tube is inserted in the bath 3. The free end of the bellows presses on a rod 4. The tip of the rod may be screwed along a thread; the extreme positions are controlled by a setscrew to correspond to the two set values of A. The rod 4 acts via a plate on the rubber membrane 5. Chamber M is open to the atmosphere, so the pressure on that side of 5 is constant. Chamber S is supplied at a fixed rate with compressed air through the capillary 6. If the pressure in that chamber gives a force that slightly exceeds the force exerted by 4, then 5 deflects slightly toward M and opens the vent tube 7. This causes the pressure in S to fall; 7 is closed, and the pressure in S starts to rise again. In practice the membrane takes up some intermediate position, in which the tube 7 is partly uncovered, and the pressure in S indicates the force on the rod. The mercury manometer 8, which is connected to S via a rubber tube, records the pressure in S.

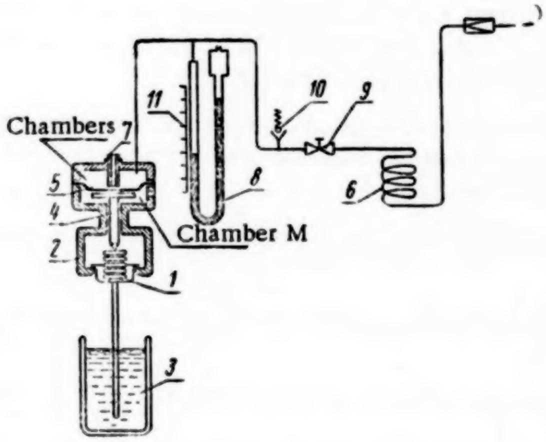


Fig. 2

The air is taken from the air line; tube 6 is 200 mm long and has a bore of 0.6 mm. The rate at which air enters 5 is almost constant, so the apparatus works reliably. The valve 9 controls the flow of air to chamber S and to the top of the U-tube 8.

The other end of the U-tube is fitted with a trap to hold the mercury if the air pressure should suddenly increase. The safety valve 10 helps to prevent such accidents by opening to the atmosphere when the pressure rises too far.

The scale 11 is calibrated directly in kilograms, to read directly the force exerted by the bellows. The scale also carries adjustable limit indicators. The head is fitted to the size of A by means of a standard piece; the apparatus is calibrated in force terms by setting the head vertically and loading the rod 4 with a weight.

# ELECTRICAL MEASUREMENTS

## WIDE-BAND PIEZOELECTRIC CONVERTERS FOR ACCELEROMETERS

E. A. Kopenin

Data required for the calculation of piezoelectric converters used in accelerometers and other transducers is given in Table 1.

The stuck-on converter (Fig. 1), consisting of a piezoelement which is connected to the moving mass and the body of the instrument by means of a polymerized adhesive, can be calculated by using an equivalent circuit (Fig. 2). On the basis of equations representing the propagation of oscillations in the equivalent circuit and the equations representing the operation of the piezoelectric element [1] we obtain the following expression which determines the voltage at the output of the converter in a state of forced harmonic oscillations when the converter is connected to the input of the amplifier with an input resistance R and input capacity $C_M$:

$$U(t)=\frac{b\kappa_2 dmK_0\left(\cos\frac{\omega l}{c}+B\sin\frac{\omega l}{c}\right)}{\left(1-\frac{\omega^2}{\omega_{10}^2}\right)\sqrt{(C_F+C_m)^2+\frac{1}{\omega^2R^2}}}e^{i(\omega t+\psi)} \tag{1}$$

where $\underline{b}$ is a coefficient which depends on the construction of the converter, $k_2$ is a coefficient which depends on the construction of the piezoelectric element, $\underline{d}$ is the piezoelectric modulus, $\underline{m}$ is the equivalent moving mass, $K_0$ is the acceleration amplitude of the surface on which the converter is fixed, $\omega$ is the angular velocity, $l$ is the length of the converter body,* $\rho$ is the density of the body, $\underline{c}$ is the speed of propagation of the body ($c = \sqrt{E/\rho}$), B is a coefficient which depends on the construction of the converter, $\omega_{10}$ is the natural frequency of the system consisting of stiffness $W_1'$ and mass $\underline{m}$, $W_1'$ is the equivalent stiffness, $C_F$ is the self-capacity of an open-circuited piezoelectric element, $\psi$ is the phase difference between the voltage at the input of the amplifier and the voltage across the piezoelectric element, $\omega_{20}$ is the natural frequency of the lid ($\omega_{20} = \sqrt{W_2/m_2}$).

Equation (1) is also applicable for calculating other types of piezoelectrical converters with the exception of converters using entrapped elements (Fig. 3). The equation obtained for the latter is of a similar form but is very cumbersome and is not given here.

The values of the coefficients $\underline{b}$ and B and of the equivalent moving mass $\underline{m}$ and stiffness $W_1'$ for various converters are given in Table 2.

The stiffness of the piezoelectric element $W_n$, the moving mass $W_M$ and the lid $W_2$ can be determined as stiffnesses of rods.

The values of the coefficients $k_2$ for various piezoelectric elements are given in Table 3.

The phase difference between the voltage at the input of the amplifier and that at the piezoelectric element can be obtained from expression:

* In designing converters on the basis of shear strains in the piezoelectric element, $l$ is understood to be the length of the equivalent body with a uniform cross section S equal to the cross section of the solid part of the actual body and stiffness $W = \frac{2W_kW_s}{2W_k+W_s}$ where $W_k$ is the stiffness of compression of the toroidal portion of the actual body and $W_s$ is the stiffness to compression of the solid portion of the actual body.

TABLE 1

| Material of which the piezoelectric element is made | Cut or direction of polarization | Piezoelectric modulus d $\left[\frac{k}{N}\right]$ | | Permittivity $\xi\sigma$ $\left[\frac{\Phi}{m}\right]$ | | Modulus of elasticity $E_\mu$ $\left[\frac{N}{m^2}\right]$ | |
|---|---|---|---|---|---|---|---|
| | | tensor notation | value $\cdot 10^{-10}$ | tensor notation | value $\cdot 10^{11}$ | tensor notation | value $\cdot 10^{-10}$ |
| Quartz | $X$ | $d_{11}$ | 2,09 | $\xi_{11}$ | 3,97 | $E_x$ | 7,75 |
| | $Y$ | $d_{11}$ | 2,09 | $\xi_{11}$ | 3,97 | $E_x$ | 7,75 |
| Rochelle salt | 45° $X$ | $\frac{d_{14}}{2}$ | 150 | $\xi_{11}$ | 268 | $E_e$ | 1,84 |
| | 45° $Y$ | $\frac{d_{25}}{2}$ | 28,1 | $\xi_{22}$ | 12 | $E_e$ | 0,99 |
| Ammonium dihydrophosphate | 45° $Z$ | $\frac{d_{36}}{2}$ | 26,4 | $\xi_{33}$ | 13,8 | $E_e$ | 1,9 |
| Barium titanate | Perpendicular to the direction of the force | $d_{33}$ | 107 | $\xi_{33}$ | 1240 | $E_z$ | 11,5 |
| Ditto | | $d_{31}$ | 56,6 | $\xi_{33}$ | 1320 | – | – |

Note: $\xi_\sigma$ is the permittivity of an open-circuited piezoelectric element, $E_\mu$ is the modulus of elasticity of a short-circuited piezoelectric element.

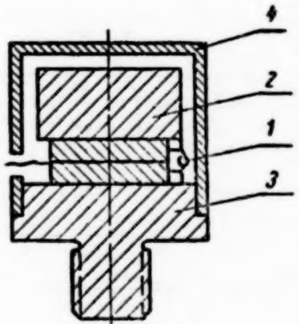


Fig. 1. Stuck-on converter designed on the basis of tension – compression strains in a piezoelectric element. 1) Piezoelement, 2) moving mass, 3) body, 4) lid.

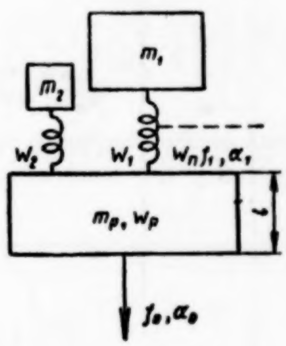


Fig. 2. Equivalent circuit of the mechanical system of a stuck-on converter designed on the basis of tension – compression strains in a piezoelectric element.

$$\psi = \operatorname{arctg} \frac{1}{\omega R\,(C_F + C_m)}. \tag{2}$$

By means of (1) and (2) the amplitude and phase-frequency characteristics of the converter can be calculated:

$$U_0 = f(\omega)\,,\quad \psi = f(\omega) \text{ for } \kappa_0 = \text{const}.$$

Equations (1) and (2) are applicable up to a frequency of $\omega = 0.75\ \omega_0$ ($\omega_0$ is the natural frequency of the converter), i.e., in the whole frequency range used in practice. Equation (2) serves to evaluate the phase shift in the same frequency range.

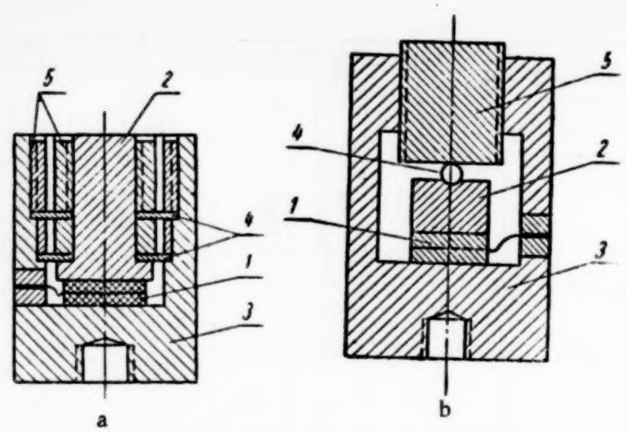


Fig. 3. Converters with entrapped piezoelectric elements. 1) Piezoelement, 2) moving mass, 3) body, 4) membrane (a) or spherical element (b), 5) plug.

TABLE 2

| Converter designation | $h$ | $m$ | $W_1'$ | $B$ |
|---|---|---|---|---|
| Stuck-on converter designed on the basis of tension-compression strains in a piezoelectric element | 1 | $m_1$ | $\frac{2.46W_n W_m}{W_n+2.46W_m}$ | $\dfrac{\frac{SE}{c}\left(1-\frac{\omega^2}{\omega_{10}^2}\right)\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\sin\frac{\omega l}{c}+m_1\omega\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\cos\frac{\omega l}{c}+m_2\omega\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\cos\frac{\omega l}{c}}{\frac{SE}{c}\left(1-\frac{\omega^2}{\omega_{10}^2}\right)\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\cos\frac{\omega l}{c}-m_1\omega\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\sin\frac{\omega l}{c}-m_2\omega\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\sin\frac{\omega l}{c}}$ |
| Converters designed on the basis of shear strain in a piezoelectric element | 1 | $m_1$ | $\frac{2\pi G l_n\left(R_1+\frac{l}{2}\right)}{l}$ | $\dfrac{\frac{SE}{c}\left(1-\frac{\omega^2}{\omega_{10}^2}\right)\sin\frac{\omega l}{c}+m\omega\cos\frac{\omega l}{c}}{\frac{SE}{c}\left(1-\frac{\omega^2}{\omega_{10}^2}\right)\cos\frac{\omega l}{c}-m\omega\sin\frac{\omega l}{c}}$ |
| Entrapped and stuck-on converter | $\frac{W_n}{W_n+W_2}$ | $m_1+m_2$ | $2.46W_2+\frac{2.46W_n W_m}{2.46W_m+W_m}$ | Ditto |

Notes: 1. $W_n$ is the stiffness of the piezoelectric element in compression, $W_2$ is the stiffness of the lid in compression, $m_1$ is the moving mass, $m_2$ is the mass of the lid, G is the modulus of rigidity, $l_n$ is the length of the piezoelectric element, $W_M$ is the stiffness of the moving mass in compression, S is the cross sectional area of the body of the converter, E is the modulus of the longitudinal elasticity of the body, $R_1$ is the internal radius of the piezoelectric element, $l = R_2 - R_1$.

2. If the mass $m_n$ of the piezoelectric element is taken into account, term m must have term $m_n/2$ added to it.

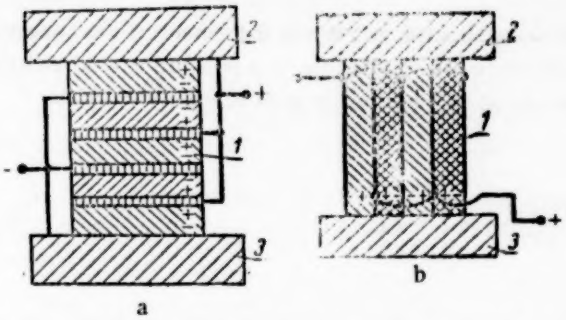


Fig. 4. Converters with complex piezoelectric elements. a) Consisting of a series mechanical connection of simple elements, b) consisting of a parallel mechanical connection of simple elements, 1 is a piezoelectric element, 2 is the moving mass and 3 is the body.

TABLE 3

| Type of piezoelectric element | Coefficient $k_2$ |
|---|---|
| Complex piezoelement consisting of series mechanically connected simple elements (Fig. 4a) | $\frac{l_f}{l_q} = n$ |
| Complex piezoelement consisting of parallel mechanically connected simple elements (Fig. 4b) | $\frac{l_f}{l_q}$ |
| Simple shear operating ring piezoelectric element | $\frac{R_2 - R_1}{l_n}$ |

Note: $l_f$ and $l_q$ are respectively distances between the piezoelement faces which react to the force and which provide the charge, $R_2$ and $R_1$ are respectively the internal and external radii of the toroidal piezoelectric element, n is the number of simple elements comprising and a complex one, $l_n$ is the length of the piezoelement.

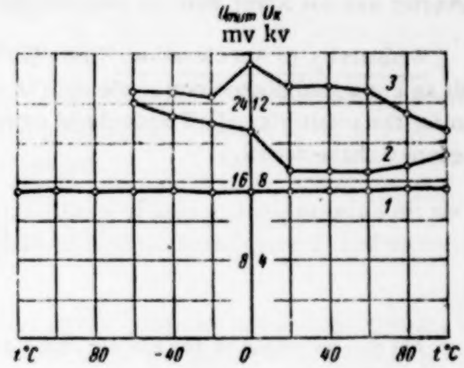


Fig. 5.

Natural Frequencies. The longitudinal natural frequency of the converter working in a state of free oscillations is determined:

for a stuck-on converter operating on the basis of tension-compression strains of the piezoelectric element by the expression:

$$\frac{SE}{c}\left(1-\frac{\omega^2}{\omega_{10}^2}\right)\cdot\left(1-\frac{\omega^2}{\omega_{20}^2}\right)-\left[m_2\left(1-\frac{\omega^2}{\omega_{10}^2}\right)+m_1\left(1-\frac{\omega^2}{\omega_{20}^2}\right)\right]\omega\,\mathrm{tg}\frac{\omega l}{c}=0 \tag{3}$$

and for an entrapped stuck-on element operating on the basis of shear strains by the expression:

$$\frac{SE}{c}\left(1-\frac{\omega^2}{\omega_{10}^2}\right)-m\,\omega\,\mathrm{tg}\,\frac{\omega l}{c}=0, \tag{4}$$

which provide good agreement with experimental data.

The natural frequency of the converters, with the exception of the one with an entrapped element, can be expressed by the following formula with an accuracy of ±10%:

$$\omega_0 \simeq \sqrt{\frac{W}{m+\frac{m_K}{3}}}, \tag{5}$$

where W is the equivalent stiffness ($W = \frac{W_n W_k}{W_n + W_k}$), $W_n$ is the stiffness of the piezoelectric element in compression (or in shear for the converters using shear strains as the basis of their operation), $W_k$ is the stiffness of the body in compression, $m_k$ is the mass of the body, m is the equivalent moving mass.

Assuming the damping coefficient to be $\xi = 0.06$ and knowing from (5) the approximate value of the longitudinal natural frequency of the converter it is possible to obtain an amplitude – frequency characteristic of a system with one degree of freedom which has the above parameters of $\xi$ and $\omega_0$. This characteristic is very close to that of the converter.

The above expressions were derived with the assumption that the transverse natural frequency $\omega_{0\ trs}$ of the converter was not lower than its longitudinal natural frequency $\omega_0$.

Sensitivity to Acceleration. From (1) and the expression giving the voltage at the output of the converter with an entrapped piezoelectric element in a state of forced harmonic oscillations it is possible to find an expression for the sensitivity of all wide-band converters to acceleration in a uniform region of their amplitude-frequency characteristic:

$$\nu=\left|\frac{U_0}{K_0}\right|=\frac{9.81\cdot 10^3 b\kappa_2 dm}{C_F+C_m}\left[\frac{\mathrm{mv}}{g}\right]. \tag{6}$$

All the notations in (6) are the same as in (1) with the exception of the converters with entrapped elements whose coefficient b is equal to:

$$b=\frac{1+\frac{W_5}{W_4}+\frac{W_5}{W_3}+\frac{m_3}{m_4}\left(1+\frac{W_5}{W_4}\right)+\frac{m_4}{m_2}}{1+\frac{W_5}{W_4}+\frac{W_5}{W_3}+\frac{W_5}{W_2}},$$

where $m_2$ is the moving mass ($m_2$ = m), $m_3$ is the mass of the plug, $m_4$ is the equivalent mass of the toroidal portion of the body, $W_2$ is the stiffness of the piezoelement in compression, $W_3$ is the stiffness in compression of the spherical element or the membrane, $W_4$ is the stiffness of the threaded connection between the plug and the body of the instrument, $W_5$ is the equivalent stiffness in compression of the toroidal portion of the body.

Systematic Errors. The amplitude-frequency error of the converter and the phase difference between the voltage at its output and acceleration can be determined from the graphs of the amplitude and phase-frequency characteristics of the converter or analytically from the following expressions:

1) at frequencies near to zero

$$\gamma_\omega\approx\gamma_H=\frac{C_F+C_m-\sqrt{(C_F+C_m)^2+\frac{1}{\omega^2R^2}}}{\sqrt{(C_F+C_m)^2+\frac{1}{\omega^2R^2}}}; \tag{7}$$

2) at frequencies in the interval between the uniform region of the amplitude-frequency characteristic (where $\gamma_\omega = \gamma_H + \gamma_b \approx 0$) and frequency $\omega = 0.75\ \omega_0$.

$$\gamma_\omega=\gamma_b=\frac{\cos\frac{\omega l}{c}+B\sin\frac{\omega l}{c}}{1-\frac{\omega^2}{\omega_{10}^2}}-1. \tag{8}$$

It will be seen from (7) and (8) that the amplitude-frequency error of the converters can be decreased at lower frequencies by increasing the time constant of the amplifier input circuit up to the point when the relationship $\omega R(C_F + C_M) \gg 1$ holds [(with $\omega R(C_F + C_M) \geq 10$ $\gamma_H \leq 1\%$ and $\psi \leq 6°$)], and at higher frequencies by increasing the natural frequency of the converter.

In addition, in order to decrease the amplitude and phase-frequency errors, electrical filters and phase correcting networks can be used.

From (6) it is possible to obtain the following expression for determining the temperature error of the converter when it is working in the uniform region of its amplitude-frequency characteristic in the temperature range Δt:

$$\gamma_t \simeq \frac{\Delta b}{b} + \frac{\Delta d}{d} - \frac{\Delta C_F + \Delta C_m}{C_F + C_m}. \quad (9)$$

where $\Delta$ is the increment of the values in question in the $\Delta t$ temperature range.

It will be seen from (9) that in order to decrease the temperature error,materials whose parameters do not depend on temperature (quartz) should be chosen, or else materials and parameters of the converter and the amplifier input circuit selected in such a manner as to cancel each other out.

Figure 5 shows experimentally obtained relations between the sensitivity of adhesive converters with piezoelectric elements made of quartz (curve 1), of barium titanate with 12% of lead titanate (curve 2) and of barium titanate (curve 3).

When measuring sinusoidal accelerations,the output voltage curve of the converter sometimes contains nonlinear distortion due to the effect on the piezoelectric modulus d of the value of the mechanical tension, or to the asymmetry of the mechanical oscillatory system, or the presence in it of nonlinear elements (for instance, a converter with an entrapped element).

TABLE 4

| | | | | |
|---|---|---|---|---|
| $\varphi$ | 2 | 1 | 1 | 0,5 |
| $\delta_1$ | 2 | 2 | 1 | 0,5 |
| $\delta_2$ | 2 | 2 | 1 | 0,5 |
| $\lvert \gamma_n \rvert$ % | 14,5 | 10,74 | 7,24 | 3,49 |

When using adhesive and entrapped adhesive converters with mechanical tensions on the piezoelements not exceeding for quartz $\sigma$ = 100-150 N/cm$^2$ and for barium titanate $\sigma$ = 30 N/cm$^2$ there are practically no nonlinear distortions [2].

When accelerations whose directions are not parallel with the axis of symmetry of the converter are measured, an error of measurement arises which is due to the converter's sensitivity in the transverse direction. Table 4 shows the absolute value of the error $[\gamma_n]$ in a converter with an X-cut quartz element with angle $\gamma$ = 45° and various values for angles $\delta_1 \delta_2$ and $\varphi$ (Fig. 6).

In order to decrease this error,it is necessary to use in the converters the above mentioned elements (with the exception of Y-cut quartz) cut with the utmost precision with respect to the main axis of the crystal, to use homogeneous piezoelectric elements,and to place the elements in the converters and the converter on the object in such a manner that perpendiculars to the piezoelement and the flat surface of the converter body coincide with the direction in which it is required to measure acceleration.

A decrease in the error $\gamma_n$ can be achieved either by compensating $\gamma_n$ by superimposing various components of $\gamma_n$ with different signs (simple piezoelements comprising a complex element can be orientated in such a way that they tend to cancel out $\gamma_n$) or by decreasing the bending moment acting on the element through shortening the element and making the center of gravity of the moving mass coincide with that of the element, by selecting an appropriate shape for the mass (this way is especially efficient when ceramic elements are used which are made of barium titanate which provide a converter with a $[\gamma_n]_{max} \leq 3\%$), or, finally, by increasing the natural frequency of the converter.

Errors due to the "cable effect." If a converter operates with an amplifier which has a high input resistance, R = $10^7$-$10^{10}$ ohms, a so-called "cable effect" occurs, which consists of the following: when a fully screened coaxial cable is connected to the amplifier and is subjected to vibration, it produces at the input of the amplifier voltages in the range of frequencies up to 500 cps amounting to 30 mv/g due to electrification by friction. This error can be practically eliminated by using graphite cables in which the surface of the insulation facing the screening is covered with a uniform layer of ground graphite with a minimum resistance as measured along the cable (not exceeding 20 kilohms per 1 m of length).

Measurement errors depend on the error of the method and the equipment used for calibrating the converters which is made in a state of forced harmonic oscillations with mechanical, electrodynamic, piezoelectric and magnetostriction equipment. The output voltages are measured by tube voltmeters and the acceleration amplitude by means of standard converters which have a very high natural frequency.

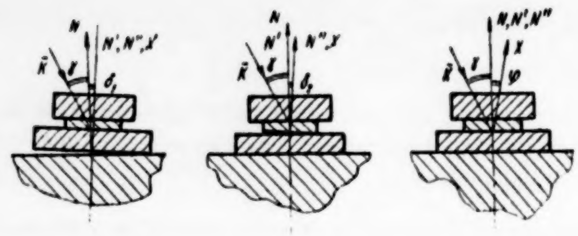

Fig. 6. Converters with a high sensivity to transverse oscillations.

If the fixing of the converter on the object under test is not sufficiently rigid, the resonance of the fixing may occur before that of the converter's mechanical system, which will increase the amplitude-frequency errors of the converter in the operating range of frequencies. This error can be eliminated by sticking the converter onto the object under test or binding it rigidly.

The error of calibration $\gamma_m$ and error $\gamma_n$ due to the effect of the transverse sensitivity are the most important. All the remaining error can be made sufficiently small by a correct choice of piezoelectric elements, the construction and parameters of the converters and the amplifier input circuit.

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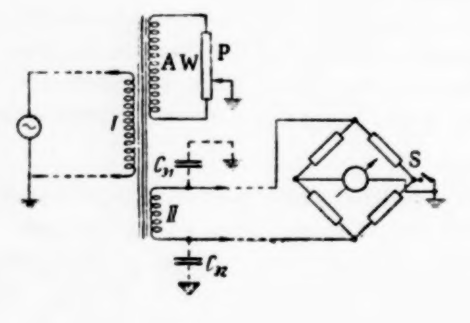
# A BALANCING TRANSFORMER FOR FEEDING AC BRIDGE CIRCUITS


G. Ya. Gurovich


Several bridge circuits require screened and balanced-to-ground transformers for their supplies [1, 2]. These transformers are very complicated in construction and require delicate balancing by means of varying the insulation thickness between the lead-out wires and the screens.

Nevertheless, these transformers have various operating defects. Thus, they can only be used with equal ratio-arm bridge. It is, of course, possible to construct a transformer for an unequal ratio-arm bridge, but only for one particular ratio. The difficulties in constructing and balancing these transformers increase with unequal ratio arms.




The absence of adjustable balancing-to-ground is another operational defect which is just as important. It is known that capacitative leakage currents in the bridge components lead to a bridge unbalance. Despite the balanced transformer the circuit as a whole becomes unbalanced. Final balancing of the bridge is made by means of a grounding* variable capacitor connected to one of the bridge units. An auxiliary resistance circuit connected in parallel with the bridge is also used for zero balancing of the null indicator, and is particularly effective in bridges with highly efficient screening [3]. The circuit does not completely eliminate the effect of leakage currents on the bridge components not included in the common screen, and is seldom used with null indicators which have a sharply unbalanced input (for instance an electronic amplifier).

The balancing transformer whose circuit is given in the figure attached provides a simple means of combining the balancing of the transformer with that of the bridge.

* In this article the term "ground" is used in a wider sense equivalent to "circuit screen." Actual grounding of the screen is not always beneficial and may not be used [3].

The special feature of the transformer is the additional winding AW which serves as a screen between the primary and secondary windings and is connected to potentiometer P with a grounded slide.

The primary winding I of the transformer is connected to the feeding oscillator, the secondary winding II to the bridge.

The distributed capacity of the bridge circuit and of the secondarywindings $C_{31}$ and $C_{32}$ are concentrated at the output terminals of the secondary winding. In view of the fact that these distributed capacities connect the secondary windingsnot only with ground, but also with circuit components which are at a certain potential to ground (remaining windings of the transformer) the equivalent capacities $C_{31}$ and $C_{32}$ should be considered as dynamic.

The main object of having an additional winding is to be able to balance capacities $C_{31}$ and $C_{32}$. This is achieved by moving the slide of potentiometer P which changes the potential differences between the additional and secondary windings. Since the interwinding capacities are determined by the construction of the transformer and remain constant, changes in the potential differences produced variations in the capacity currents and thus in the value of the dynamic equivalent capacities.

A high degree of balance of the circuit can be achieved by consecutively balancing the bridge with switch S closed and then balancing potentiometer P with the switch open. The bridge measurement results will thus be obtained at the same time.

In the case of a bridge with unequal ratio-arms, a ratio of capcities $C_{31}$ and $C_{32}$ equal to that of the bridge arms is attained in a similar manner.

Since the balancing is done only by means of the voltage between the additional and secondary windings, a very thin wire can be used for the additional winding. Such a winding hardly increases the size of the transformer, and with a high resistance potentiometer P it hardly affects the power consumed.

The use of this transformer in an instrument for measuring the loss angle of insulating materials by the bridge method at audio frequencies provides the required accuracy with a tube voltmeter MVL-2M used as a zero indicator.

## SUMMARY

This transformer with an additional (balancing) winding can be successfully used in measuring bridge circuits with unbalanced null indicators (one of whose terminals is connected to ground) and also when a single feeding transformer is used in circuits with varying ratios of ratio arms.

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# EQUIPMENT FOR MEASURING MAGNETOSTRICTION IN THE TEMPERATURE RANGE OF -180° to +440°C

B. M. Yanovskii, E. A. Sokolova and V. S. Gegin

One of the characteristics of magnetostriction in normal samples is its temperature coefficient $\beta$, which represents the changes in magnetostriction $\lambda$ with a temperature variation of 1°C, i.e., $\beta = d\lambda$ dt. The numerical value of $\beta$ depends on the material and must be determined experimentally for each normal sample.

In developing the work carried out in 1956 [1] in the magnetic laboratory of the VNIIM (All-Union Scientific Research Institute of Metrology) a new equipment for measuring magnetostriction in the temperature range of −180 to +440°C was designed.

The equipment consists of (Fig. 1) two parts: the magnetometric which serves to measure the magnetometric which serves to measure the magnetization J of the sample and the magneto-striction which measures the constriction with a given magnetization J.

The magnetometric part of the equipment consists of an astatic magnetometer 1, and to magnetizing coils 2 and 3.

The astatic system of the magnetometer consists of two permanent magnets of a cylindrical form connected by a duralumin tube. The magnets are made of a "magneco" alloy.

The distance between the magnets is about 100 cm, and the magnetic moment of each is 188.6 cgs units.

The system is suspended on taut phosphor bronze wires and has adjusting heads at the top and the bottom for altering the tension on the wire and the angle of twist.

The magnetometer is placed in the central part of the equipment on a solid brass frame 4, and closed by a brass tube. At its top and bottom where the magnets are fixed, housings are provided for hold ng copper dampers.

A mirror is fixed to the astatic system and placed opposite a plane parallel glass window in the tube.

For calibration of the magnetometer in field strength units the lower magnet is placed in the center of Helmholtz rings 5.

The calibration of the magnetometer in magnetic moment units (or magnetization) is carried out by means of permanent magnets with known magnetic moments which have the same size and shape as the sample under test.

When the magnetometer is calibrated the permanent magnet is placed instead of the sample under test in a quartz tube fixed to the interferometer 6.

Results of calibration with different magnets have shown that the scale division value does not depend on the magnetic moment within the limits of measurement accuracy and amounts to 29.9 cgs units/division .

The error in the measurement of magnetization does not exceed ± 1% with magnetometer deflections of the order of 300 mm.

The magnetizing coils are connected in opposition and placed on both sides of the magnetometer on slides which can be moved by means of a micrometer for the purpose of balancing out each others' fields.

One of the coils contains a thermostatically controlled heater for temperatures of +20 to +440°C and the other a gas cooled refrigerator form temperatures of +20 to −180°C.

The coils consist of multilayer solenoids placed vertically.

Each solenoid has a winding consisting of three sections, one of them has a single layer winding which serves to compensate for the vertical component of the earth's magnetic field, the other two a multilayer windings for the magnetizations of the sample. The resistance of each coil amounts to 8.5 ohms with the two multi-layer sections connected in series.

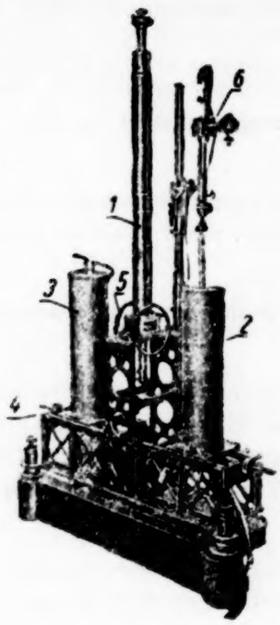


Fig. 1.

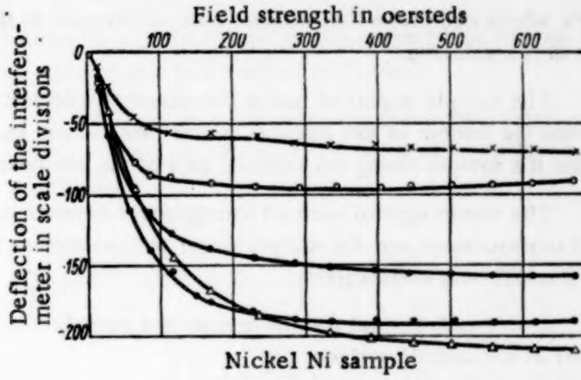


Fig. 2.

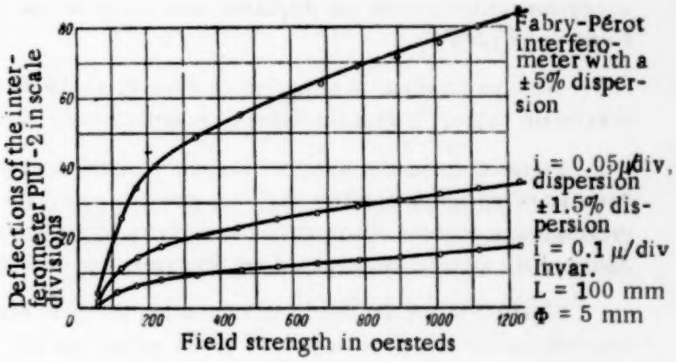


Fig. 3.

Constants $K_1$ and $K_2$ with the two sections connected in series have the following values at the center $K_1$ = 112.1 oe/amp for the coil with the heater and $K_2$ = 113.8 oe/amp for the coil with the refrigerator. The single layer coils have the following respective values for their constants, $K_3$ = 5.09 oe/amp and $K_4$ = = 5.04 oe/amp. The nonuniformity of the field along the coil axis does not exceed ±3% at a distance along the axis of ±5 cm from the center.

With a supply voltage of 240 v it is possible to obtain a field strength of 1,500 oe.

The thermostatically controlled heater consists of a tubular oven with a bifilar wound platinum wire. Tests have shown that with a current of I = 3.5 amp the temperature reaches 440°C. The error in the temperature measurement amounts to ±0.5%.

The thermostatically controlled refrigerator consists of a combination of a Dewar flask with liquid nitrogen and a vacuum glass tube.

Tests of the refrigerator have shown that it will provide in the range of −180 to +20°C a steady temperature within ±1 to 2°C for 5 minutes.

The temperature gradient along the sample amounts to 0.30°C/cm.

The magnetostriction part of the equipment consists of a combination of an interferometer 6 type PIU-2 or PIU-1 with a quartz tube for fixing the sample. Inside the tube there is another quartz tube which is connected to the end of the moving rod of a PIU interferometer.

The interferometer measures the variations of the sample length in absolute units since its scale is calibrated by the light wavelength admitted by the light filter.

In order to extend the range of magnetostriction measurements a Fabry-Perot standard was used for the first time in conjunction with interferometer PIU providing a scale division of 0.01 μ/div with the normal accuracy of an interferometer.

The interferometer is mounted on the same stand as the sample holder, and is provided with a regulating screw which can place the internal tube, connected to the moving rod of the interferometer, along the vertical axis of the solenoid.

The sample is placed inside the external tube resting with one end of its bottom while the other end rests against the bottom of the internal quartz tube, whose end has stainless nonmagnetic steel cap which serves to center the sample along the vertical axis of the solenoid.

The advantages of such an arrangement consists in the absence of metallic parts between the moving rod of the interferometer and the sample under test; moreover fused quartz has a very small linear temperature coefficient and a small heat conductivity.

A chromel-alumel thermocouple in a porcelain casing is placed inside the stationary quartz tube in its center at the sample surface.

Magnetostriction test results of samples made of different materials taken at various temperatures and measured on an interferometer scale with division of 0.05 $\mu$/div showed that in all the materials magnetostriction is greatly affected by temperature, the relation, however, varies with the type of material used. Thus for nickel magnetostriction curves are displaced with rising temperature towards the Y-axis, shortened and approach the Curie point (385°C).

With an increase in temperature from 20 to 440°C the curve rise in the case of iron approached a certain maximum value. With a set value of magnetization, however. magnetostriction rises with temperature.

Figure 2 shows the relations between constriction and field strength for a nickel sample taken with a Fabry-Perot standard which confirm that it is possible by means of the Fabry-Perot standard to extend the limits of measurement without changing the sensitivity of the interferometer, thus whereas the interferometer scale has 100 divisions the deviations obtained are equivalent to over 200 divisions.

Figure 3 shows the results of measuring an invar sample with different scale division values of the PIU interferometer: 0.1 $\mu$/div and 0.05 $\mu$/div as well as with a Fabry-Perot standard. These results show that the value of the interferometer scale division does not depend on the sample under test and that the Fabry-Perot standard does not introduce any additional errors.

Over the whole range of measurements the relation between the deviations obtained with the Fabry-Perot standard and those obtained on the interferometer PIU scale remains constant within 5% limits.

On the basis of the data obtained on the relation between striction and temperature, magnetostriction temperature coefficients were calculated for various temperatures $T_1$, magnetizations J and field strengths H. Figures 4 and 5 show graphs of the relation of $\beta$ to temperature at various values of J and H for invar and iron.

The results thus obtained show that the magnetostriction coefficient has different values for different materials and depends both on temperature and on the magnetization of the sample.

The accuracy of measurement of magnetostriction with a scale division of 0.05 $\mu$/div can be evaluated by the error $\Delta\lambda = 0.03 \cdot 10^{-6} - 0.04 \cdot 10^{-6}$ obtained from a number of repeated measurements at various values of magnetization J.

Taking this error of $\Delta\lambda$ as set, it is possible to determine the value of the permissible magnetization measurement error $\Delta J$ which does not affect the accuracy of $\lambda$. Since $\lambda = f(J)$,

$$d\lambda = f'(J)\,dJ = \frac{d\lambda}{dJ}\,dJ,$$

when assuming finite values we obtain approximately:

$$\Delta J = \frac{\Delta\lambda}{\frac{d\lambda}{dJ}}.$$

The derivative $d\lambda/dJ$ can be found from the curves of the relation between $\lambda$ and J as the relation of increment $\Delta\lambda$ to increment $\Delta J$.

Hence it will be seen that the permissible error $\Delta J$ depends to a great extent on the shape of the curves $\lambda$-J. Thus for nickel this error in various parts of the curve is expressed by the terms given in Table 1.

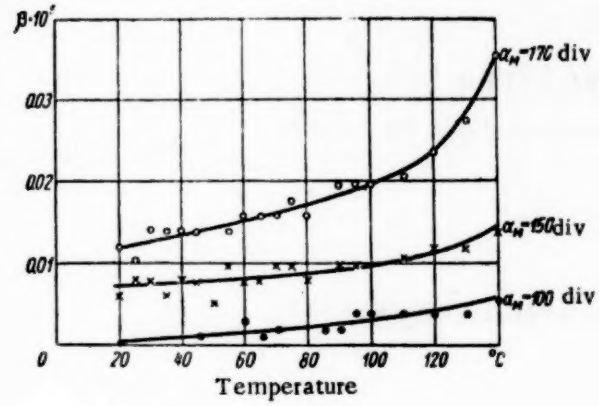


Fig. 4.

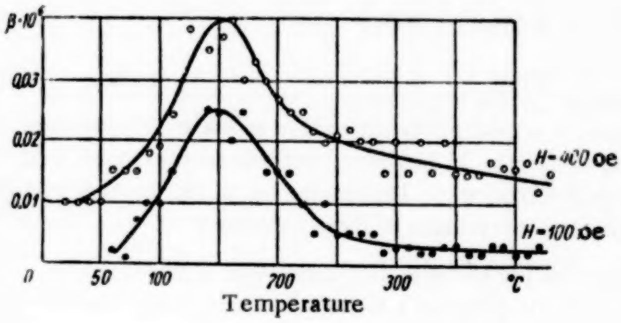


Fig. 5.

The error in determining the temperature coefficient for a given value of J is found from the relationship:

$$\frac{\Delta\beta}{\beta}=\frac{\Delta(\lambda_1-\lambda_2)}{\lambda_1-\lambda_2}+\frac{\Delta(T_1-T_2)}{T_1-T_2}=\frac{2\Delta\lambda}{\lambda_1-\lambda_2}+\frac{2\Delta T}{T_1-T_2}, \quad (1)$$

where $\lambda_1$ and $\lambda_2$ are two consecutive values of striction at temperatures $T_1$ and $T_2$.

Noting that $\frac{\lambda_1-\lambda_2}{T_1-T_2}$ for small values of differences becomes a derivative $d\lambda/dT = \lambda'$ we obtain:

$$\frac{\Delta\beta}{\beta}=2\left(\frac{1}{\lambda'}\cdot\frac{\Delta\lambda}{T_1-T_2}+\lambda'\frac{\Delta T}{\lambda_1-\lambda_2}\right), \quad (2)$$

whence it will be seen that $\Delta\beta/\beta$ depends on the derivative $\lambda'$, i.e., on the form of the function $\lambda(T)$. If $\lambda$ changes rapidly with temperature, ($\lambda'$ is very large), the error $\Delta\beta/\beta$ is greatly affected by the error in measuring temperature, if on the contrary $\lambda$ is affected but little by temperature, the largest error in determining $\beta$ will be due the error in measuring striction $\Delta$ . However in both cases the error can be considerably decreased if $\lambda'$ is a constant, i.e., when the relation between $\lambda$ and T is linear.

In fact when measuring $\lambda'$, intervals $\lambda_1-\lambda_2$ and $T_1-T_2$ can be taken arbitrarily large, making both terms in the right hand side of equation (2) small independently of the value of $\lambda'$.

TABLE 1

| J in cgs units | Interferometer scale divisions | | | $dJ$ | $\frac{d\lambda}{dJ}$ | $\Delta J$ | |
|---|---|---|---|---|---|---|---|
| | $\lambda$ | $d\lambda$ | $\Delta\lambda$ | | | in cgs units | в % |
| 250 | 22.4 | | | | | | |
| 260 | 25.4 | 2.9 | 0.34 | 10 | 0.29 | 1.17 | 0.5 |
| 340 | 50 | | | | | | |
| 350 | 53.4 | 3.4 | 0.27 | 10 | 0.34 | 0.8 | 0.25 |
| 390 | 63.6 | | | | | | |
| 400 | 65.6 | 2.0 | 0.20 | 10 | 0.20 | 1.0 | 0.25 |

TABLE 2

| Magnetization J in divisions of the magnetometer scale | $\lambda\cdot10^6$ | $(\lambda_1-\lambda_2)\cdot10^6$ | $T_1-T_2$, °C | $\frac{2\Delta\lambda}{\lambda}\cdot\frac{\lambda}{\lambda_1-\lambda_2}$ | $\frac{2\Delta T}{T_1-T_2}$ | $\frac{\Delta\beta}{\beta}$ |
|---|---|---|---|---|---|---|
| 100 | 0.15 | 0.08 | 40.0 | 0.038 | 0.05 | 0.085 |
| 150 | 0.70 | 0.43 | 40.0 | 0.033 | 0.05 | 0.083 |
| 170 | 1.20 | 0.50 | 40.0 | 0.048 | 0.05 | 0.098 |
| 180 | 1.50 | 0.80 | 40.0 | 0.038 | 0.05 | 0.088 |
| 200 | 2.48 | 1.00 | 40.0 | 0.050 | 0.05 | 0.100 |
| 210 | 3.15 | 1.43 | 40.0 | 0.044 | 0.05 | 0.094 |
| 220 | 4.00 | 1.98 | 40.0 | 0.040 | 0.05 | 0.090 |

As an example Table 2 gives numerical values of the error $\Delta\beta/\beta$ for invar assuming $\Delta\beta/\beta$ = 1% and $\Delta T$ = 1°C.

Results of direct measurements of magnetization showed that the equipment provides measurements of J with an error not exceeding the one obtained above by theoretical means.

Similarly the results of temperature coefficient calculations provide errors in determining $\beta$ which are in good agreement with those calculated from (1).

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# ORGANIZING THE PRODUCTION OF HIGH-TENSION COMPRESSED GAS FILLED CAPACITORS

M. A. Bykov and V. A. Volkova

Our electrotechnical industry does not produce three-terminal high-tension capacitors filled with compressed gas.

The high-tension bridges MDP of the "Tochélectropribor" plant are fitted with air capacitors which are made for 10 and 35 kv, which is not an efficient procedure. It is practically impossible to make air capacitors for higher voltages than these since the capacitors become too large. If, however, compressed gas is used as an dialectric the capacitors can be reduced to a fraction of their former size. Experience has shown the high metrological qualities, stability, negligibly small loss angle and other advantages of these capacitors.

In an article entitled "A standard gas-filled capacitor for 100 kv" (Élektrichestvo, No. 1, 1956) it was reported that sulfur hexafluoride $SF_6$ (élegas ) used as a dielectric provides a further reduction in the size of capacitors as compared with the normal nitrogen filled type.

In addition to bridge circuits for measuring $\delta$ and C, high-tension capacitors are also required for other measuring purposes. They can be used as high-tension parts of capacity voltage dividers, for instance in checking transformers for any voltage limit up to 600 kv.

Capacitor production must definitely be organized.

# MEASUREMENTS AT HIGH AND ULTRA-HIGH FREQUENCIES

## A DIFFERENTIAL METHOD OF MEASURING THE FREQUENCY OF ELECTRICAL OSCILLATIONS

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The differential method is widely used for measuring the frequency of highly stable electrical oscillations [1-4].

It is of interest to analyze systematically the available data and describe the differential method in general terms.

General description of the method. In order to measure a given frequency of electrical oscillations it is necessary to add this frequency to a standard one, measure the beat frequency and from it calculate the error $\delta_x$ and the actual value of the measured frequency $f_x = f_{x\,nom} - \delta_x$.

It is known [5] that the addition of two oscillations with similar frequencies $e_1 = E_1 \cos 2\pi f_1 t$ and $e_2 = E_2 \cos 2\pi f_2 t$ produces complicated beating oscillations

$$e = e_1 + e_2 = E(t)\cos[2\pi f_1 t + \Phi(t)], \tag{1}$$

where

$$E(t) = E_1 \sqrt{1 + 2h\cos 2\pi Ft + h^2}; \tag{2}$$

$$\Phi(t) = \operatorname{arctg} \frac{h \sin 2\pi Ft}{1 + h\cos 2\pi Ft}; \tag{3}$$

$$h = \frac{E_2}{E_1}$$

The beat frequency F equals the difference between the added frequencies

$$F = f_1 - f_2. \tag{4}$$

Oscillations similar to beats can also be obtained when two frequencies which differ considerably from each other are added. For this purpose mutually perpendicular oscillations at these frequencies should be added.

Let us assume two oscillations:

$$\vec{e}_1 = \vec{E}_1 \cos 2\pi f_1 t. \tag{5}$$

$$\vec{e}_2 = \vec{E}_2 \cos 2\pi f_2 t. \tag{6}$$

where

$$f_1 = lf_0 + \Delta_1;\; f_2 = kf_0 + \Delta_2;\; \vec{E}_1 \perp \vec{E}_2,$$

and k and $l$ are mutually prime integers.

Let us write these expressions in the form:

$$\vec{e}_1 = \vec{E}_1 \cos 2\pi(lf_0+\Delta_1)t,$$
$$\vec{e}_2 = \vec{E}_2 \cos 2\pi(kf_0+\Delta_2)t,$$

whence

$$\arccos\frac{e_1}{E_1} = 2\pi(lf_0+\Delta_1)t, \tag{7}$$
$$\arccos\frac{e_2}{E_2} = 2\pi(kf_0+\Delta_2)t. \tag{8}$$

Multiplying (7) by $\underline{k}$ and $l$ (8) by $l$ and subtracting (8) from (7) we obtain:

$$k\arccos\frac{e_1}{E_1} - l\arccos\frac{e_2}{E_2} = 2\pi(k\Delta_1 - l\Delta_2)t$$

or finally:

$$\cos\left(k\arccos\frac{e_1}{E_1} - l\arccos\frac{e_2}{E_2}\right) = \cos 2\pi(k\Delta_1 - l\Delta_2)t. \tag{9}$$

For each instant $\underline{t}$ this equation produces an equation of a certain figure on plane $\vec{e}_1\vec{e}_2$.

If $k\Delta_1 = l\Delta_2$ we have

$$\cos\left(k\arccos\frac{e_1}{E_1} - l\arccos\frac{e_2}{E_2}\right) = 1.$$

If $k\Delta_1 \neq l\Delta_2$ the figure will change shape at the rate

$$F = k\Delta_1 - l\Delta_2 = kf_1 - lf_2. \tag{10}$$

If $F \ll f_2$ the shape repetition frequency is similar to the beat frequency although it is not equal to the difference of the added frequencies.

Addition of electrical oscillations is accomplished in a mixer circuit by the reaction of these oscillations on the same or different parameters of the circuit. In a linear circuit the spectra of added oscillations do not change. In nonlinear circuit the spectra of added oscillations do not change. In nonlinear circuits the spectra of the added oscillations are changed and the difference frequency component is produced in a pure form.

A cathode-ray tube can serve as an example of a linear mixer circuit; in it two oscillations of different frequencies react on the deflection of the electron beam, one in the horizontal and the other in the vertical directions.

A square-law detector can serve as an example of a nonlinear mixer circuit; when two electric currents of different frequencies flow through it, in its load we shall obtain in addition to harmonic and combination frequency components also a current of a difference frequency.

Measurement of the frequency of beats. The frequency of beats can be measured by a direct or indirect method. If its value consists of fractions of cps it should be measured by the indirect method: the number of beats $\underline{n}$ should be counted over a given time interval $\underline{t}$ measured on a stop watch, and the beat frequency obtained

from the formula F = n/t. Indirect measurements can be made visually by watching the pointer of an indicating instrument connected in the mixer load circuit, or the displacement of an electron beam on the screen of a cathode-ray tube; or else, audibly, by listening to beats on earphones, or, finally, automatically, by means of a counter which records beats.

If the beat frequency is over 5-10 cps it is usually measured by a direct method using a frequency meter, or by a zero beat method using an audio oscillator and an oscillograph.

Calculation of the measured frequency error. The beat frequency is related to the error of the measured frequency by definite expressions which depend on the frequencies of the added oscillations. If the standard frequency is equal to the nominal value of the measured frequency $f_{st} = f_{x\,nom}$, the measured frequency error is equal to the beat frequency:

$$\delta_x = F. \tag{11}$$

If $f_x = \frac{l}{k} f_{st}$, the beat frequency $F = l f_{st} - k f_x$, and the measured frequency error is

$$\delta_x = \frac{l}{k} f_{st} - f_x = \frac{l f_{st} - k f_x}{k} = \frac{F}{k}. \tag{12}$$

If $l$ and k harmonics instead of the basic frequencies are compared, when $l f_{st} = k f_{x\,nom}$, the measured frequency error is calculated from the same formula with $l$ and k representing the number of the harmonics. Formula (11) is a particular case of (12) when $l = k = 1$.

The relative error of the measured frequency is expressed by the formula:

$$\delta_{xo} = \frac{\delta_x}{f_{x\,nom}} \tag{13}$$

or in terms of the beat frequency:

$$\delta_{xo} = \frac{F}{k f_{x\,nom}}. \tag{14}$$

Errors of measuring frequencies of electrical oscillations by the differential method arise owing to errors of the measuring circuit and errors in measuring the beat frequency.

In practice, for measuring frequencies by the differential method, in addition to a mixer and beat frequency measuring device, other auxiliary devices and means of transmitting oscillations from the source to the place of measurement are required.

Instability of the circuit parameters leads to phase changes in the oscillations passing through the system and, hence, to a change in the frequency of the oscillations by the amount

$$\xi_\varphi = \frac{\Delta\varphi}{2\pi\Delta t} \tag{15}$$

Here $\Delta\varphi$ is the variation in the angle during time $\Delta t$.

The errors introduced by the measuring circuits are usually small [6, 7]. The most important effect on the accuracy of the frequency determination is produced by the error in measuring the beat frequency.

In direct measurements of the beat frequency, this error is determined by the error of the frequency-measuring device $\Delta F$, in the indirect method, by the error of the measuring time $\Delta t_1$ and the error in counting the number of beats $\Delta n$.

In practice it is often difficult to allocate errors $\Delta t_1$ and $\Delta n$, it is, therefore, usual to evaluate a general error in measuring time

$$\Delta t = \sqrt{\Delta t_1^2 + \Delta t_2^2} \left(\text{where } \Delta t_2 = \frac{\Delta n}{F}\right).$$

which is due to the stop-watch error and the inaccuracy in counting; the error in determining the beat frequency is expressed by the formula:

$$\xi_t = F\frac{\Delta t}{t} \tag{16}$$

If, in the direct measurement of the beat frequency, an error $\Delta F$ was made, the relative error of measurement becomes:

$$\xi_{F_0} = \frac{\Delta F}{kf_{x\,\text{nom}}} = \delta_{xo}\frac{\Delta F}{kF}, \tag{17}$$

and if, in indirect measurements, an error $\Delta t$ was committed, it becomes:

$$\xi_{t_0} = \delta_{xo}\frac{\Delta t}{t}. \tag{18}$$

The total relative error of frequency measurement is calculated from one of the following formulas:

for a direct measurement of the beat frequency

$$\xi_{f_0} = \sqrt{\sum \xi_{F_0}^2}, \tag{19}$$

where $\Sigma\xi_{F_0}^2$ is the sum of the squares of the errors of instruments which comprise the measuring circuit;

for an indirect measurement of the beat frequency:

$$\xi_{f_0} = \sqrt{\sum \xi_{\psi_0}^2 + \xi_{t_0}^2}, \tag{20}$$

where $\Sigma\xi_{\psi_0}$ is the sum of the squares of the relative errors due to the phase instability of the measuring circuit elements and $\xi_{t_0}^2$ is the relative error of the beat durations.

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# AN INSTRUMENT FOR MEASURING THE Q FACTOR AND EQUIVALENT RESISTANCE OF QUARTZ RESONATORS

E. D. Novdorodov

The most convenient method of measuring the Q factor of high-Q quartz resonators is by estimating the decay time of their free oscillations. In this case the Q factor is determined from the formula:

$$Q = \pi \frac{fT_k}{\ln k},$$

where $f$ is the natural frequency of the quartz resonator, $T_k$ is the time during which the amplitude of the resonator oscillations will decrease to $1/k$ of its original value.

In order to increase the accuracy of measurements and simplify them, the Khar'kov State Institute of Measures and Measuring Instruments, on the suggestions of L. D. Bryzzheva, adopted the following method of measurement. The voltage of freely decaying oscillations of a quartz resonator is fed to a voltage indicator first, through a potential divider with a voltage ratio $\underline{k}$, and then directly. By means of a stop watch, the time $T_k$ is measured between the instants the indicator registers the same voltage reading. A cathode-ray oscilloscope was normally used as an indicator. When measuring the Q factor of crystal tuning forks, an instrument amplifier with a tube voltmeter whose input had a built-in potential divider were also used.

The instrument developed by the authors of this article provides automatic measurement of time $T_k$, and the possibility of extending this method of measurement to resonators with a relatively short decay time $T_k$ down to 10 μsec, whereas, by means of a normal stopwatch, the measured time cannot be less than several seconds. The measurements of durations less than 10 μsec is limited by the error due to the dispersion of the operating time of relays $P_1$ and $P_2$ (0.5 μsec).

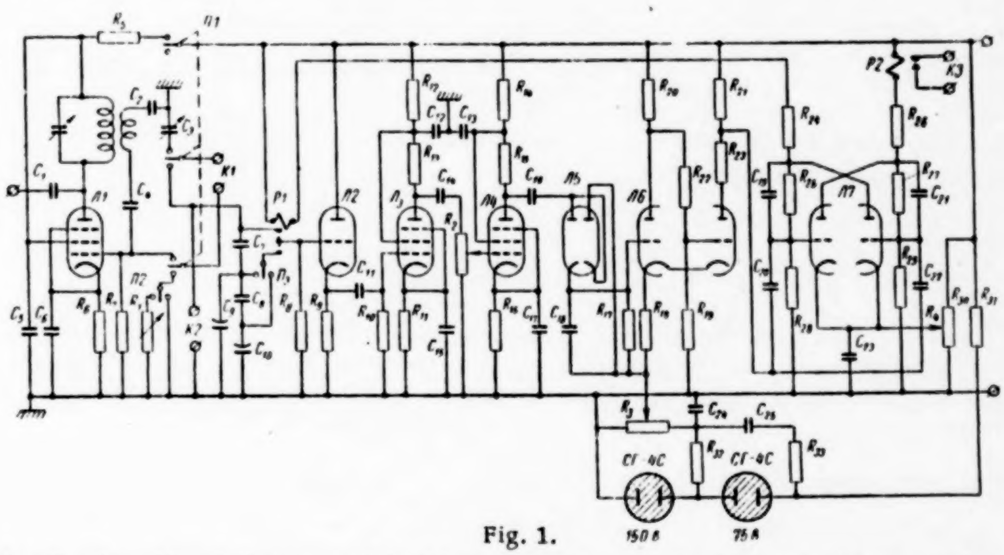

Fig. 1.

*The following Russian abbreviations are retained in the figure: Л = tube, Тр = transformer, М = megohm, к = kilohm, мк = μf or μh, н = mμf or mμh, п = μμf or μμh, and в = volt. For individual tube designations see appendix to No. 1 of this year.*

Figure 1 shows the circuit of the instrument. The quartz resonator is excited in a single tube ($T_1$) oscillator with a capacity bridge in the feedback circuit. The resonator is connected into one of the bridge arms (terminals $K_1$), and the bridge is balanced. Thus, the static capacity of the resonator is compensated, and the feedback operates only at the resonant frequencies of the quartz crystal when the bridge is unbalanced. By changing the tuning of the anode circuit it is possible to excite the crystal either at its fundamental frequency or one of its overtones.

After excitation, the quartz resonator is disconnected from the oscillator switch $S_1$ (this switch simultaneously disconnects the anode supply of the oscillator) and reconnected to the capacity potential divider. In order to eliminate the shunting effect on the resonator of resistances present in the circuit, a capacitor whose reactance is a small fraction of the equivalent reactance of the resonator, is connected in parallel with the divider to terminals $K_2$. Switch $S_2$ is then in its right hand side position. Under these conditions the quartz resonator is in a state of free-decaying oscillations.

The voltage obtaining across the resonator is fed through the potential divider to cathode follower ($T_2$), which has a high input impedance, and then to wide-band amplifier ($T_3$ and $T_4$). The amplified voltage is fed to detector ($T_5$), represented by section 1 in Fig. 2a. The rectified voltage (section 1 in Fig. 2b) is fed to the trigger ($T_6$) which at the instant the voltage drops to $V_{tr}$ changes its state and transmits to the counter ($T_7$) which follows it a positive pulse 2 (Fig. 2c).

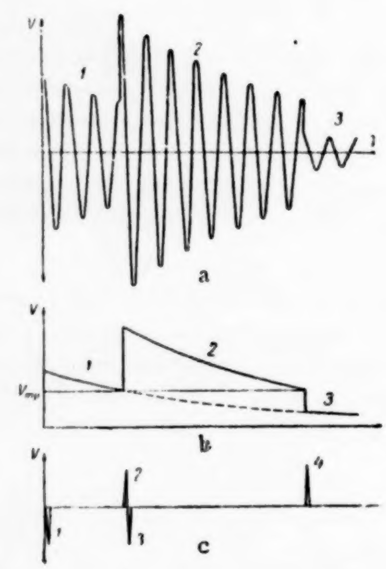

Fig. 2. a) Voltage at the amplifier output; b) voltage at the trigger input ; c) pulses at the trigger output.

The counting circuit operates relay $P_1$ which disconnects the divider and connects the whole voltage of the quartz resonator to the input of the cathode follower, i.e., increases the voltage at that instant by a factor of $\underline{k}$. The curve of the amplifier output voltage which rises accordingly is shown in Fig. 2a section 2 and the voltage after detection in Fig. 2b section 2. As soon as the voltage at the trigger input rises above $V_{tr}$, the trigger returns to its original state and the conting circuit receives a negative pulse 3 (Fig. 2c), which does not operate it. Relay $P_2$ operates simultaneously with $P_1$ and shorts terminals $K_3$ to which a timer of any desired type may be connected.

When the voltage at the trigger input again falls to $V_{tr}$, the counting circuit again receives a positive pulse 4 (Fig. 2c), operates and connects the divider, disconnecting the timer. Thus the timer counts thethe time during which the amplitude of the quartz resonator decreases by a factor of $\underline{k}$.

The Q factor of the quartz resonator is calculated from the time registered by the timer. The ratio of the divider can be made to equal $\underline{e}$ or $e^2$ (according to the position of switch $S_3$). Hence the value of the Q factor is calculated from the formulas:

$$Q = \pi f T e \quad \text{or} \quad Q = \frac{1}{2} \pi f T e^2$$

At the instant the quartz resonator is switched from the oscillator to the divider, the trigger generates a negative pulse 1 at its output (Fig. 2c), but since the counting circuit is adjusted by means of potentiometer $R_4$ in such a way that it is only responds to positive pulses, the initial negative pulse does not affect the operation of the circuit.

Potentiometer $R_3$ serves to alter the tripping voltage $V_{tr}$ of the trigger.

It is also possible to measure the equivalent resistances of quartz resonators by means of this instrument. For this purpose, after measuring the Q factor, variable resistance $R_1$ is connected in series with the quartz resonator by means of switch $S_2$ and the Q factor is measured again, which becomes smaller due to the losses in resistance $R_1$. It is obvious that the newly obtained Q factor is inversely proportional to the sum of the equivalent resistance of the quartz resonator $R_q$ and the series resistance $R_1$ and hence:

$$\frac{Q_0}{Q} = \frac{R_q + R_1}{R_q},$$

where $Q_0$ is the Q factor of the quartz resonator without resistance $R_1$.

Hence:

$$R_q = \frac{R_1}{\frac{Q_0}{Q} - 1}.$$

The relative error in measuring the Q factor when the decay time is over 0.1 sec is determined mainly by the relative error of the timer used and in practice is equal to the latter. The relative error in measuring $R_q$ for $R \simeq R_q$ is approximately 2.5 times the Q factor error. When the decay time is smaller that 0.1 sec the measurement error increases due to the relatively larger time of relay operation.

Above instrument was used for measuring quartz resonators at the Khar'kov State Institute of Measures and Measuring Instruments.

## CHECKING PRECISION WAVEMETERS WITHOUT A SECONDARY FREQUENCY STANDARD

V. Ya. Volodarskii

Heterodyne frequency meter VVT-D. Instruction 219-55 of the Committee of Standards, Measures and Measuring Instruments on checking frequency meter VVT-D provides for the use of a secondary frequency standard (SFS).

The checking of the VVT-D instrument with sufficient accuracy is possible, however, without the SFS, i.e., in the majority of inspection establishments.

The checking of the heterodyne VVT-D frequency meter without the use of a SFS consists of an external inspection and checking of the operating conditions, checking of the crystal calibrator, determining the frequency shift in the rough and precise oscillators with changing test conditions, checking the stability of the rough and precise oscillators, determining the error of the rough oscillator, checking the interpolator and determining the sensitivity of the frequency meter.

External inspection and the check of operating conditions is carried out according to instruction 219-55.

The crystal calibrator is checked by comparing the 10 kc obtained at the phone jacks of the VVT-D with the standard 1,000 cps transmitted by radio or with the frequency of a standard oscillator whose error does not exceed $\pm 1.5 \cdot 10^{-6}$

The error of the crystal calibrator frequency must not exceed $\pm 5 \cdot 10^{-6}$.

In order to measure the value of the frequency drift of the rough and precise oscillators at varying operating conditions of the frequency meter under test, another auxiliary VVT-D meter of high precision should be used. To obviate any pulling,the coupling between the instruments should be as small as possible.

The frequency drift is determined as follows. The switch marked "Oscillators" of the VVT-D set under test is thrown to the "Rough" position and the frequency of the oscillator is measured by means of the auxiliary precision frequency meter. Then the "Oscillators" switch is thrown to the "Rough and precise" position and the frequency drift of the rough oscillator under differing operating conditions is determined by means of the auxiliary frequency meter. The precision oscillator of the set under test should be turned in such a way as to prevent its frequency being picked up by the auxiliary VVT-D set. The auxiliary frequency meter must not be switched in any way between the first and second of these measurements. The measurements are repeated three times at all the frequencies of the rough oscillator in intervals of 10 Mc. The relative frequency drift must not exceed $\pm 1.2 \cdot 10^{-5}$.

The frequency drift of the precision oscillator is checked in a similar manner with the switch thrown from the position "Precise" to the position "Precise and rough." Measurements are made in three points of the precise oscillator scale. The relative frequency drift of the precise oscillator must not exceed $\pm 1.3 \cdot 10^{-5}$.

The checking of the stability of the rough and precise oscillators during the period required for measurement (2-3 min) is made by means of the same method, as the determination of their drift. The stability is checked at the bottom, middle and top of the rough and precise oscillator scales. The frequency of either oscillator must not change by more than $\pm 0.5 \cdot 10^{-5}$ in 3 min.

The frequency error of the rough oscillator is checked by means of the precision oscillator of the set itself at points at 100, 110, 120 Mc etc. The frequency error of the rough oscillator must not exceed one division of its scale ($\pm 2$ Mc).

The interpolator is checked by means of the crystal calibrator of the VVT-D under test at 10 kc. For this purpose the pointer of the interpolator is set at zero and the precision oscillator is set to a frequency at a 10 kc point and the required scale setting of the interpolator for this frequency is found. Next the interpolator is checked at a 5 kc point (if required it can also be checked at 3.33 and 6.67 kc points) by beating with the 10 kc of the crystal oscillator of the set itself.

The interpolator is checked at three frequencies of the precision oscillator, namely 18.5, 20 and 22 Mc. The interpolator error must not exceed the smallest graduation of the interpolator scale by more than a factor of 2.5. If necessary, the sensitivity of the instrument under test can be checked by a standard signal generator of the type GSS-12 (or GSS-7, GSS-D). The sensitivity of the frequency meter is determined as the input power required to close completely the magic eye connected to its output at maximum gain. The sensitivity of the VVT-D instrument must not be less than 1 $\mu$w.

When all above requirements are satisfied the VVT-D frequency meter is considered to be satisfactory.*

High precision wavemeter 44-I. In 1956 we developed a step-by-step method of checking wavemeter 44-I without using a secondary frequency standard.

It is known that the error of the 44-I wavemeter is determined by the error of calibration of the decimeter oscillator, its frequency drift, when the main switch is changed from the position "Oscillator correction" to position "Precise measurement, and by the error of interpolation and the instability of the decimeter oscillator during the measuring time (2 min). By evaluating these errors it becomes possible to judge of the quality of the wavemeter as a whole.

External inspection, checking of the operation and checking of the resonance wavemeter of a 44-I instrument is carried out according to instruction 218-55. The error of the decimeter oscillator calibration is checked by a crystal oscillator whose error must not exceed $\pm 1 \cdot 10^{-5}$. The error of the crystal oscillator is determined according to instruction 215-54. To ensure accuracy of checking, it is recommended to use standard frequencies of 10 and 15 Mc, transmitted over the radio, or calibrating oscillators KG-B or KG-V, which have been checked and corrected beforehand with an accuracy not less than $\pm 1 \cdot 10^{-6}$. Coupling with the crystal oscillator should be obtained by placing on the crystal oscillator tube $T_3$ (6Zh4) 2-3 turns of wire, the main switch being thrown to the "Oscillator correction" position, and the tumbler switch marked "100-20 Mc" to the "100 Mc" position.

The determination of the decimeter oscillator frequency drift when changing from the "Oscillator correction" position to the "Precision measurement" position is made by means of an auxiliary 44-I wavemeter, which is switched to the "Precision measurement" position. The frequency drift is measured at every multiple point of 100 Mc. The relative frequency drift must not exceed $\pm 2 \cdot 10^{-5}$.

For determining the interpolator error it is necessary to remove the multivibrator divider tube $T_2$ (6N8), having opened the rear (rectifier) side of the instrument. The condition of operation of the crystal generator is not changed substantially thereby, since, with the tumbler switch in position "20 Mc", tube $T_2$ does not pass any anode current. A standard frequency of 1 Mc is connected to jack No. 4 of the tube panel and the body of the set, the interpolator scale "Measurement" is set to zero, and zero beats are obtained by means of the vernier.

* At present an instruction is being issued on testing high precision VVT-D wavemeters.

After this, point "20 Mc" of the interpolation scale is calibrated by the zero beats of the standard frequency of 1 Mc. Next, having obtained the correction for the "zero" point of the scale, a zero beat of the decimeter oscillator under test with a harmonic of the standard 1 Mc oscillator near the point on the interpolator scale marked "10 Mc" is obtained and its calibration error is determined. If required, the interpolator scale can be checked at 1 Mc intervals, using the 100 kc as a standard frequency. The error of the interpolator scale must not exceed at any point $\pm 2 \cdot 10^{-5}$ of the nominal value of the decimeter oscillator frequency, or 0.2 of its scale division.

The interpolator scale is checked at three frequencies in the working range of the instrument, which correspond to the minim, maximum and mean values of the "Measurement" scale.

Instability of the decimeter oscillator frequency during the measurement is determined by means of the crystal calibrator of the set itself by observing the frequency drift for 2 min, after 40 min and 2 hours from the time the set was switched on. The measurements are made on the interpolator scale with the main switch in the "Oscillator correction" position. The relative instability must not exceed $\pm 2 \cdot 10^{-5}$ during 2 min, after 40 min and $\pm 1 \cdot 10^{-5}$ after 2 hours from the time the set is switched on.

# THERMOTECHNICAL MEASUREMENTS

## A NEW METHOD FOR THE DETERMINATION OF THE EFFECTIVE WAVELENGTH OF OPTICAL AND PHOTOELECTRIC BRIGHTNESS PYROMETERS

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In the calibration and testing of a technical brightness pyrometer against a source which is not a black-body source, it is essential to know the effective wavelength in order to take into account the spectral characteristics of the source. This is particularly important in the case of photoelectric brightness pyrometers in which the effective wavelength may be considerably different from the value of 0.65 $\mu$ at which the calibration of standard temperature lamps is normally carried out. In the operation of brightness pyrometers,it is essential to know the effective wavelength in order to calculate the correction for the fact that the incandescent body whose temperature is to be measured is not a perfect black-body. For these purposes,the value of the effective wavelength must be known,and to an accuracy of the order of $\pm$ 0.01-0.02 $\mu$.

At the present time,new types of optical and photoelectric pyrometers, both mass-produced and experimental, are being used. In this connection it became necessary to devise simple and reliable methods for measuring the effective wavelength, which would be convenient for both optical and photoelectric pyrometers. In the case of photoelectric pyrometers, the working spectral interval is limited in a different way than in the case of optical instruments and is usually not so well defined. The use of a wide spectral interval means that the effective wavelength will depend on the spectral composition of the radiation which is being measured. This often leads to large differences between values of the effective wavelength for different types of pyrometers, or different instruments of a given type, and also to a change in the value of the effective wavelength of each instrument when the spectral characteristics of the emitter are altered.

Existing methods for measuring the effective wavelength of pyrometers have a number of disadvantages, in particular, they are usually complicated, insufficiently accurate, and cannot be used to determine the value of the effective wavelength in the required temperature intervals.

The Groot method, after modernization at VNIIM, in which the lamp with a frosted glass envelope is replaced by a ribbon lamp with colored glass, is free of some of the above disadvantages. However, this method remains insufficiently accurate since the accuracy of the result depends on the errors in the preliminary calibration of the pyrometer.

The determination of the effective wavelength of photoelectric pyrometers from the dependence of the photocurrent on the measured temperature, as suggested for color pyrometers, cannot be used in the case of brightness pyrometers since a linear relation between the brightness and the photocurrent is not necessary and is practically never obeyed.

New method for measuring the effective wavelength. In this method two light filters are chosen, one of which raises the color temperature of the source of radiation (for example, a temperature lamp),and the other leaves it. The spectral curves of the light filters should intersect at a wavelength close to the effective wavelength of the pyrometer under consideration. Keeping the current through the temperature lamps constant, the two filters are placed in turn in front of the lamp, and the corresponding temperatures are measured through the two filters, using the pyrometer under investigation. These measurements can be used to determine the required effective wavelength. The brightness temperature of the lamp measured through the two light filters 1 and 2,

is shown in the figure as a function of wavelength. Suppose that when the brightness temperature is measured with either of the two filters in position, the readings of the pyrometer are the same and equal to $S_0$. It is obvious that this is only possible when the effective wavelength of the pyrometer $\lambda_e$ is equal to $\lambda_0$. In that case, one can write down the following equation for the amount of light received by the eye of the observer, or the photoelement, from the lamp with the first and the second light filters in position:

$$\varepsilon_{c1}\int_0^\infty b^0_{\lambda T_{c1}} V_\lambda \tau_\lambda \, d\lambda = \varepsilon_{c2}\int_0^\infty b^0_{\lambda T_{c2}} V_\lambda \tau_\lambda \, d\lambda.$$

Here $\epsilon_{c1}$ and $\epsilon_{c2}$ are the monochromatic emissive powers of the lamp with the first and the second light filters in position respectively, $b^0_{\lambda T_{c1}}$ and $b^0_{\lambda T_{c2}}$ is the spectral brightness of a black-body at the wavelength $\lambda$ and temperature $T_{c1}$ and $T_{c2}$ respectively, $V_\lambda$ is the spectral sensitivity of the photoelement of the photoelectric pyrometer, or the visibility in the case of an optical pyrometer, and $\tau_\lambda$ is the spectral transmission coefficient of the light filter placed in the optical system of the pyrometer (red glass in the case of an optical pyrometer).

The left-hand part of the equation $\epsilon_{c1}L_{T_{c1}}$ corresponds to the light from the lamp with the first filter in position, and the right-hand part, $\epsilon_{c2}L_{T_{c2}}$, to the light from the lamp with the second light filter in position.

From the calibration data for the lamp for each of the light filters, giving the brightness temperature as the function of wavelength, it is known that

$$\varepsilon_{c1}\, b^0_{\lambda_0 T_{c1}} = \varepsilon_{c2}\, b^0_{\lambda_0 T_{c2}} = b^0_{\lambda_0 S_0}.$$

Hence,

$$\frac{L_{T_{c1}}}{L_{T_{c2}}} = \frac{b^0_{\lambda_0 T_{c1}}}{b^0_{\lambda_0 T_{c2}}}$$

and consequently, the effective wavelength $\lambda_0$ refers to the temperature interval between $T_{c1}$ and $T_{c2}$.

If the readings of the pyrometer in the measurement of the brightness temperature, using the first and the second light filters, are different, then the value of the effective wavelength is calculated from the measured temperature difference $S_1$-$S_2$.

The brightness temperature of the lamp $S_1$ with the first filter in position, depends on the true temperature of the lamp T and the transmission coefficient of this filter $\tau'_\lambda$ in the following way

$$\frac{1}{S_1} - \frac{1}{T} = -\frac{\lambda \ln \tau'_\lambda}{c_2} - \frac{\lambda}{c_2}\ln \varepsilon_\lambda \tag{1}$$

where $\epsilon_\lambda$ is the monochromatic emissivity of the lamp at the wavelength $\lambda$. An analogous expression may be written down for the brightness temperature of the lamp with the second light filter in position:

$$\frac{1}{S_2} - \frac{1}{T} = -\frac{\lambda}{c_2}\ln \tau''_\lambda - \frac{\lambda}{c_2}\ln \varepsilon_\lambda \tag{2}$$

Subtracting (2) from (1) we have

$$\frac{1}{S_1} - \frac{1}{S_2} = -\frac{\lambda}{c_2}\ln \frac{\tau'_\lambda}{\tau''_\lambda}. \tag{3}$$

Using equation (3) one can determine the effective wavelength of the pyrometer if the brightness temperatures $S_1$ and $S_2$ are measured. An analysis analogous to that given for the case $S_1 = S_2 = S_0$ shows that the effective temperature determined in this way refers to the temperature interval between $T_{c1}$ and $T_{c2}$.

Equation (3) holds without any limitations as to the difference between $\lambda_e$ and $\lambda_0$; it is correct for any time temperature of the lamp T, and for any spectral characteristics of the light filters. However, as in the modernized Groot method, the quantities $S_1$ and $S_2$ must be accurately measured, i.e., the pyrometer must be accurately calibrated, since calibration errors influence the measurement of the effective wavelength.

The effect of calibration errors may be excluded if the light filters are chosen so that the effective wavelength of the pyrometer is close to $\lambda_0$. Under this condition $S_1$ and $S_2$ will be close to $S_0$ and equation (3) may be simplified assuming that $\tau'_\lambda - \lambda'' \ll \tau_0$:

$$\frac{1}{S_1} - \frac{1}{S_2} \simeq \frac{S_2 - S_1}{S_0^2} = \frac{\lambda}{c_2} \ln \frac{\tau_\lambda}{\tau_\lambda^{\bullet}} \simeq$$

$$\simeq \frac{\lambda}{c_2} \ln \left( 1 + \frac{\tau_\lambda' - \tau_\lambda^{\bullet}}{\tau_0} \right) \simeq \frac{\lambda}{c_2} \cdot \frac{\tau_\lambda^{\bullet} - \tau_\lambda}{\tau_0}. \tag{4}$$

Let us transform this equation assuming that in the expansion of $\tau'_\lambda - \tau''$ into a series, only the first term need be taken for the spectral region used in the pyrometer under consideration. We then have

$$\frac{S_1 - S_2}{S_0^2} = \frac{\lambda_0}{c_2} \cdot \frac{1}{\tau_0} \left( \frac{\partial \tau_\lambda}{\partial \lambda} - \frac{\partial \tau_\lambda^{\bullet}}{\partial \lambda} \right) (\lambda_e - \lambda_0),$$

$$\lambda_e - \lambda_0 = \frac{(S_1 - S_2)\, \tau_0 c_2}{S_0^2 \lambda_0} \cdot \frac{1}{\dfrac{\partial \tau_\lambda'}{\partial \lambda} - \dfrac{\partial \tau_\lambda^{\bullet}}{\partial \lambda}}. \tag{5}$$

It follows from equation (5) that:

1. When the difference $\lambda_e - \lambda_0$ is small, a large relative error in the measurement of this difference may be allowed. For example, when $|\lambda_e - \lambda_0| \ll 0.1\ \mu$, it is sufficient to measure it to within 10%. Correspondingly, one may allow a high (a few percent) error in the remaining quantities in equation (5). This is so in the case of $S_0$, i.e., an accurate calibration of the pyrometer and the temperature lamp is unnecessary. Similarly, there is no need for high accuracy in the determination of the characteristics of the light filter, i.e., the values of $\tau_0$ and $\partial\tau/\partial\lambda$, and also the difference between the brightness temperatures $\Delta S$.

2. The admissible absolute error in the difference between brightness temperatures depends on the difference between the slopes of the spectral characteristics of the light filters. The bigger the difference between the slopes, the more sensitive the measurement, and hence this difference should be chosen to be sufficiently large.

3. It is necessary to know $\lambda_0$ sufficiently accurately. The value of $\lambda_0$ is independent of the temperature of the lamp, which is obvious from simple physical considerations.

Choice of the light filters and technique of measurement of the effective wavelength. Light filters which satisfy the above requirements may be prepared from colored glasses PS-9 and SZS-17. The glass PS-9 lowers, and the glass SZS-17 raises, the color temperature of a lamp with a tungsten ribbon, in the wavelength interval 0.6-0.7 $\mu$. The glass thickness which determines the temperature interval to which the effective wavelength is assigned, is determined from the spectral curves, or experimentally, by trial and error. Thus 1 mm thick PS-9 glass, and 2.4 mm thick SZS-17 glass, will allow a measurement of the effective wavelength in the interval 1100-2200°C and the value of $\lambda_0$ is about 0.655 $\mu$.

With constant current through the lamp, corresponding to a brightness temperature within the limits of the working part of the scale of the pyrometer, the lamp may be calibrated with the aid of a spectral pyrometer to give the brightness temperature as a function of wavelength for the PS-9 and SZS-17 glasses. Using the calibration data, one can then calculate the color temperature of the lamp with either of the two filters in position, and then the brightness temperature difference $\Delta S = S_1 - S_2$ as a function of wavelength.

To determine the effective wavelength with the aid of the pyrometer under consideration, one has to find the difference $\Delta S = S_1 - S_2$. To do this, the sensitivity of the pyrometer, i.e., the value of the smallest division of the indicating instrument, need be known only approximately in order to determine $S_1 - S_2$ to a limited accuracy.

If it is required to carry out measurements with a different current through the lamp than that for which it has been calibrated using the spectral pyrometer and the light filters, the transition to the new spectral pyrometer and the light filters, the transition to the new current may be carried out with the aid of equations (3) or (5), without recalibrating the lamp. In general, it is possible to get by without the calibration of the lamp together with the light filters with the aid of a spectral otrometer, and instead measure the spectral transmission coefficients of the light filters in the spectral interval under consideration, which is sufficient for the subsequent calculation using equation (5). In both cases, the temperature of the lamp $S_0$ is determined roughly from the calibration of the pyrometer, or the lamp itself, and the admissible error is a few tens of degrees.

Error in the determination of $\lambda_e$ of brightness pyrometers. The improved Groot method and the method put forward above, were used to determine $\lambda_e$ for visual brightness pyrometers, in particular, type OPK pyrometers, photoelectric brightness pyrometers FP-3 and "Fotopir" S-1, and in the selection of photoelements in the manufacture of FEP-3 TsLA pyrometers.

The use of this method in the case of photoelectric pyrometers enables one to choose the photoelement so that all the manufactured instruments had $\lambda_e$ the same to within 0.01 $\mu$. In the corresponding selection of light filters, the method may be used both in the manufacture and in the checking and calibration of infrared brightness pyrometers. For these pyrometers, the calculated $\lambda_e$ are particularly unreliable and experimental methods have not so far been forthcoming.

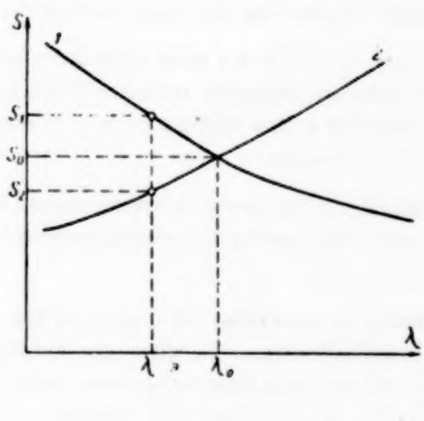
The error in the determination of $\lambda_e$ according to the new method, which does not require preliminary calibration, consists of two components, namely, the error in $\lambda_0$ and in the difference $\Delta S$. The error in $\lambda_0$, when it is determined with a spectral photometer or a spectral pyrometer, is about $0.0015\,\mu$. It must be borne in mind that the value of $\lambda_0$ may be different for different specimens of the same glass, and changes slightly with the temperature of these glasses.

The error in the difference $\lambda_e$-$\lambda_0$ is determined by the error in $S_1$-$S_2$. The latter quantity is $\pm(2\text{-}3)^\circ$ in the case of photoelectric and optical pyrometers, which corresponds to an error in $\lambda_e$-$\lambda_0$ of $\pm(0.002\text{-}0.003)$ $\mu$. If the temperature of the lamp during the calibration and the determination of $\lambda_e$ varies within $\pm50^\circ$C, then the additional error in $\lambda_e$-$\lambda_0$ is $\pm(0.0007\text{-}0.001)$ $\mu$.

Thus the error in the determination of the effective wavelength for visual and photoelectric brightness pyrometers is

$$\sigma=\sqrt{(0.0015)^2+(0.003)^2+(0.001)^2}\simeq 0.004 \quad \mu$$

which is quite sufficient for the calibration, checking, and exploitation of a technical brightness pyrometer.



# THE QUALITY OF ELECTRICITY METERS

I. N. Osher

The production of electricity meters has considerably increased in recent years and a considerable effort has been devoted to the modernization of their construction. However, the meters still suffer from a number of shortcomings due to inadequate production technology, and sometimes, insufficient operational testing of the individual subassemblies.

In order to improve the quality of electricity meters the VNII of the Committee for Standards, Measures and Measuring Instruments has carried out a further study during 1958 of the operating characteristics of electricity meters and the causes of their shortcomings.

In December 1958, a meeting was held in the VNII of the Committee and the problem of electricity meters was discussed with representatives of operating and repair organizations, the Mytishchi and Moscow electricity meter factories, the Gosplan of the RSFSR, the Moscow Town and District Sovnarkhozes, and the Mosgorispolkom.

The meeting approved measures taken by the manufacturing establishments which were aimed at the improvement of the electrical meters manufactured by them (improvements in the construction of the metering mechanism, strengthening of the body, and better wear characteristics of the lower bearing were introduced in single-phase meters; in three-phase meters, a cast support came into use and measures were taken to improve the whole production technology).

The meeting noted that the currently produced meters have substantial deficiencies.

The participants in the meeting considered that it is necessary to remove the causes of all these deficiencies in the shortest possible time. The meeting decided to pay particular attention to an increased useful life of the meters (without repair) when designing new types of meters, since this leads to an economy in the use of the national industrial potential and of the working time.

It is essential to begin (not later than the second quarter of 1959) the manufacture of electricity meters in which the clip-on cover box will make inaccessible the input leads at the meter terminals.

A considerable number of electricity meters in the rural areas have to be repaired because of their inability to withstand lightning discharges. It is therefore necessary to improve the formers of the current coils, the insulation between the turns, and the insulation of the voltage coils with respect to the body, and increase the capacity of the coils to withstand surge overvoltages.

The meeting decided that, in general, all the reactive meters should be fitted with pawls; reactive meters without pawls should be manufactured only when specially ordered; improved packaging of the meters by the manufacturers was also asked for.

The meeting underlined the necessity of increasing the quality of the materials and semimanufactured articles supplied to the manufacturing establishments, e.g., wires (including stainless steel wire for the shafts of the metering mechanisms and the spring of the upper bearing) grease, balls, jewels, sheet and strip aluminum, and particularly, the enamelled wire supplied by the Shcherbakovsk factory.

The meeting drew attention of the VNII of the Committee to the necessity of ensuring the interchangeability of the components and sub-assemblies of single-phase meters during their modernization in the manufacturing establishments.

In order to reduce high operating costs, it will be necessary to produce meters whose working life is twice the present life, and this will justify their increased cost.

The deficiencies of the electricity meters which were mentioned in the resolution of the meeting, refer to the devices produced by the Leningrad, Vilno, Mytishchi and Moscow factories.

It was proposed that the resolution should be discussed at production meetings of the manufacturing works.

From the Editorial Board. The Editorial Board of the present Journal has been receiving letters pointing out the deficiencies of electricity meters. For example, the Director of the Electricity Meter Laboratory of the Energozbyt of the Kransodarsk Sovnarkhoz, P. A. Maslovskii, informs us about constructional deficiencies of currently produced meters, and points out that the standardization of the meters and their components is inadequate. Spare parts for meters which are not in current production are not being manufactured; there is a shortage of spares even for the currently manufactured meters. P. A. Maslovskii suggests an All-Union Meeting to discuss the problem of electricity meters, which could take place during 1959.

# FIRST ALL-UNION SCIENTIFIC TECHNICAL CONFERENCE OF WORKERS IN THE WEIGHING MACHINE INDUSTRY

S. I. Gauzner

The first All-Union Scientific Technical Conference of Workers in the weighing machine industry was held in Moscow during January 14-16, 1959. The conference was attended by over 200 representatives of weighing machine manufacturing and repairing factories, the NIIVESPROM, the SKBIM, the Committee for Standards, Measures and Measuring Instruments, its Institutes and control laboratories, and the organizations concerned with the design and operation of measuring instruments.

The principal specialist of the Gosplan USSE, S. I. Lukichev, spoke about possible developments in the manufacture of weighing machines during 1959-1965, and the specialization of weighing machine factories. New trends in the development of weighing machine manufacture were considered in a paper read by the Deputy Director of NIIVESPROM, V. A. Stolyarov. S. I. Gauzner (Committee for Standards, Measures and Measuring Instruments) dealt with problems of technical control in weighing machine industry.

In addition to these main papers, eighteen contributions were heard on the automation of weighing operations in the case of granular materials and liquids, laboratory metrological balances, general purpose balances, recording.devices, and problems connected with the technology of manufacture of weighing instruments. In addition to the development work being carried out at NIIVESPROM and SKBIM, a discussion took place of the work being done at the Design Office of the Dzerzhinskii Kiev weighing machine factory, the Scientific Research Institute for nonferrous metals, the All-Union Scientific Research Institute for building and transport mechanical engineering, the Institutes of the Committee, the "Tekstil'pribor" factory, and a number of other organizations.

The conference noted the great achievements of the Soviet weighing machine industry, such as the development and assimilation of periodic and continuous action measuring hoppers used in the various branches of industry, mass production of a large and diverse group of automatic dose balances and complex weighing instruments for metallurgy, construction of electronic microbalances, weightless laboratory balances, and many other weighing instruments.

Twenty participants in the conference took part in the discussion on the above contributions.

The shortcomings of the weighing machine industry were justifiably criticized, among them, insufficient progress in the production of general purpose dial type balances, inadequate standardization of the balance components, poor quality of the analytical balances produced by the Kharov factory, the table-type balances produced by the Tulinovsk factory, the shop-type balances of the Bobruisk and Tomsk factories, and particularly, the dial heads made by the Kokchetavsk factory. It was observed that together with new devices, old antiquated balances are still being manufactured.

The participants in the conference paid great attention to organizational and technological d ficiencies in the repairing organizations. On the whole, the repairing organizations maintain a low technological level; moreover, they are not adequately supplied with spares and instruments and the cost of repairs remains high.

The resolution of the conference includes recommendations for the elimination of deficiencies in the design, production, and repair of weighing instruments. It was stressed that it would be desirable to hold similar conferences annually and that their proceedings should be published.

## ESTABLISHMENT OF A WORLD CENTER FOR THE COMPILATION STORAGE, AND DISSEMINATION OF IGY DATA

In accordance with the decision of the Special International Committee of the International Geophysical Year (IGY), a World Center for the compilation, storage and dissemination of IGY data was established in Moscow and receives materials from all the stations carrying out observations as a part of the IGY program.

The address of the Center is: Moscow, V-296, Molodezhnaya ul., d. 3, tel. VO-05-87.

The Center has reading rooms and the equipment suitable for work on the data. Moreover, for a special fee the Center can forward to interested persons or organizations, any material possessed by the Center. Access to the materials kept at the Center can be obtained by interested persons on the production of a reference from the organization employing them.

## M. F. ROMANOVA

On March 1, 1959, the death has occurred, in her 66th year and after a long and serious illness, of Mariya Fedorovna Romanova, professor, doctor of technical sciences, and head of the Department of Fundamental Units of the All-Union Scientific Research Institute for Metrology.

Mariya Fedorovna began her working life in 1916. After graduating from the Department of Physics and Mathematics of the Advanced Institute of Educarion for Women with a first class diploma, she remained with the Institute as an assistant in the Department of Physics.

Soon after the founding of the State Optical Institute, Mariya Fedorovna took up a post in that Institute, and began her scientific activity under the direction of academicians D. S. Rozhdestvenskii and A. A. Lebedev. Here M. F. Romanova showed great aptitude for accurate experimental work. Her work in high resolution interference spectroscopy has established her reputation both in the Soviet Union and abroad.

Her monograph "Interference of light and its applications" which was published in 1937 remains almost the only textbook for those beginning work in interference measurements.

In the Laboratory of Academician A. A. Lebedev, M. F. Romanova began work in interferometry which was later continued at VNIIM.

From 1938 onwards, Prof. M. F. Romanova was in charge of the Optical Laboratory at VNIIM, where a group under her direction, and with her direct participation, carried out one of the important metrological researches which were published under the title "A comparison of the standard meter No. 28 with the wavelength of light," and served as the basis for the development in the Soviet Union of ideas on the transition to units of measurement based on atomic constants. The method put forward by M. N. Romanova in 1940 for measuring large end-standards in terms of wavelengths of light, which took the form of an original instrument, was awarded the D. I. Mendeleev prize.

During the Second World War, M. F. Romanova continued her work at the Sverdlovsk branch of VNIIM. Here she was concerned with a number of problems of importance to the defense industry, and was rewarded with the Order of the Labor Red Banner for this work.

On her return to Leningrad Mariya Fedorovna directs with increased energy all the work on linear measurements at VNIIM. She was not only involved in research work, but took an active part in the development of Soviet optical instruments. The unique interferometer for measuring end-standards up to 1200 mm long, which was developed by her together with a group of her students, was awarded in 1958 the first class diploma of the All-Union Industrial Exhibition.

As a representative of the USSR, M. F. Romanova took an active part in the work of the International Consultative Committee for the determination of the meter.

Because of her great erudition, culture, and deep knowledge, Prof. M. F. Romanova was able to unite round herself a number of physicists and engineers representing the school of Soviet metrologists working on measurements of length. The work of the school and the work of Prof. M. F. Romanova has brought Soviet metrology into a leading position in linear measurements.

Mariya Fedorovna did much work in the teaching of specialists in the advanced educational institutes of Leningrad.

With the death of M. F. Romanova, Soviet science has lost one of its great specialists and a talented scientist who devoted all her life to work in the service of the Soviet Nation.

Mariya Fedorovna, friend and teacher, will live in the hearts of her students and colleagues.

## ON THE IMPROVEMENT OF THE URT-4 APPARATUS MADE BY "ÉTALON"

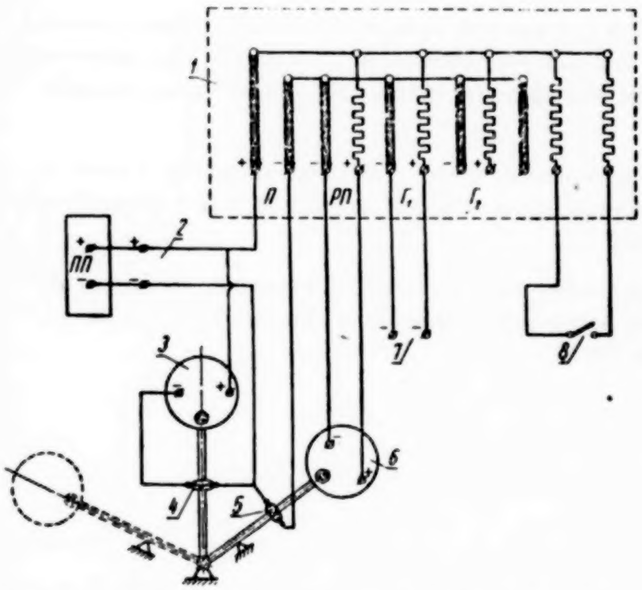
N. I. Rusalovich

The URT-4 apparatus, which is designed for checking radiation pyrometers and is made by the "Étalon" works, suffers from serious constructional defects.

The operating instructions put out by the "Étalon" works recommend that when checking the telescope of the radiation pyrometer of type RP separately from its meter, it is necessary to use a switching panel.

However, this panel is not a part of the apparatus and is not supplied by the above works. In practice this means that before each check it is necessary to assembly an additional circuit consisting of an external panel, leads, switch, etc., all of which occupies an appreciable amount of space, makes the apparatus look clumsy, and causes unnecessary loss of time.

In order to simplify the operation of the URT-4 apparatus, the author has introduced the following additions to it:




The scheme for the improvement of the URT-4 apparatus using a panel of mercury switches. 1) Resistance bank for the radiation pyrometer; 2) terminals for connecting the potentiometer; 3) standard radiation pyrometer in its working position; 4) mercury switch closed; 5) mercury switch open; 6) radiation pyrometer under tests not in its working position; 7) terminals for connecting a millivoltmeter; 8) switch (closed without the millivoltmeter, open with the millivoltmeter).

1. A bank of resistors was built into it.

2. Terminals have been added so that a calibrating potentiometer or a millivoltmeter can be connected when testing the whole set, as well as a push-button key which can be used in changing over from separate tests to the over-all test.

3. Two mercury switches were mounted on hinged rods for the automatic switching of the standard and the tested telescopes when the hinged arms move from the vertical to the inclined position.

These additions considerably simplify the work involved, reduce, the time of testing, and exclude possible faults and errors in measurements because of the reliability of the mercury contacts and the automatic switching.

The auxiliary apparatus (see Fig.) is hidden under the base plate, and on the top of this plate there are only the necessary terminals, the switch, and four flexible wires for connecting the standard and the tested telescopes.

The Leningrad "Étalon" works should introduce the necessary constructional additions to the URT-4 apparatus so that it can be used in testing laboratories without further modification.

From the Editorial Board. VNIIM has informed us that the work planned for 1959 includes the modernization of the URT-4 apparatus and the remarks made by the author of the present paper will be taken into account.

## ON THE REVIEW OF THE INSTRUCTIONS NO. 88

T. S. Zlatkis

The technical management of the Committee for Standards, Measures and Measuring Instruments has reissued, during 1957, Instructions No. 88 for the acceptance of potentiometric apparatus.

Some of the sections in these Instructions are very much out of date, and in our opinion the Instructions themselves require amplification and revision.

Thus, for example, in para. 3 it is recommended that in the absence of a megger, the insulation of a potentiometric apparatus can be checked with the aid of a battery. It is hardly necessary to point this out these days, since almost every laboratory now possesses a megger.

At the same time, the new edition does not include any recommendations as to the screening of potentiometric apparatus.

Moreover, it is desirable to use as supplies for potentiometric apparatus the mass-produced stabilized power-packs of type VVS-1 or VS-12, and hence it would be desirable to have clear instructions as to the possibilities of using such power-packs, and recommendations as to what additions and changes are necessary in their circuits.

Currently, our industry produces potentiometers PPTV-1 and with voltage dividers DN-1, potentiometers R2/1 with voltage dividers R-5, potentiometers R-375, and potentiometers PPTN-1. Naturally, the Instructions should be designed for use with these types, since all the new apparatus is furnished with the above potentiometers.

Finally, in the new editions the following corrections must be made. The statement in Fig. 1 reads "$B_2$ - storage battery supplying the voltage circuit," while on page 6 it is indicated (and this is in fact correct) that the storage battery $B_2$ is used to supply instruments under test.

From the Editorial Board. The Technical Management of the Committee of Standards, Measures and Measuring instruments informs us that the remarks made above will be taken into consideration when the Instructions are revised at VNIIK during the first half of 1959.

## IDLING TIME OF MEASURING INSTRUMENTS

P. N. Stebelev

In order to ensure better use of the measuring facilities in the manufacturing departments of the Alchevsk Metallurgical Factory, the KIP and automation section introduced a system for checking the idling time of the measuring instruments, caused by poor maintenance by the workers of the KIP section. According to this system, the valuation of the work contributed by the workers in the KIP and automation section, and in particular, the bonus payments, depend on the reduction of the idling time of the measuring instruments.

The introduction of this measure resulted in the considerable shortening of the idling time of instruments in all section of the factory. Thus, before the introduction of the system, the idling time in the blast furnace section was 7.9% of the total working time, and after the introduction of the system, this was reduced to 1.6%. The idling time of instruments in the various sections has been reduced, and in some of them almost completely eliminated.

Results of an investigation carried out by the employees of the Lugansk GKL showed that after the above system was introduced, the general technological state of the measuring instruments maintained by the KIP section of the factory was considerably improved.

The organization of the above system should be tried in other establishments also.